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Whistled Languages

With 40 Figures

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Preface

This monograph deals with curious and little-known acoustic systems of communication based on whistling that are in use at the present time in many parts of the world and have had, on the evidence available, even greater currency in the past. In spite of their wide distribution, they have not so far received the attention they might have been expected to attract: linguistically and in other ways they are most interesting. For it should be realized that they are much more than mere codes or conventional systems of signals; they function in exactly the same way as speech (in the sense we normally use the term), being in fact rather extraordinary realizations of the languages spoken in the regions where they occur. They utilize the vocabulary, grammar and, in many cases to a large extent, the phonology of the local speech. However their phonetic system is profoundly modified acoustically and (in some cases less so) from the point of view of articulation, because the glottal tone of everyday communication, the "voice", is replaced by a whistle which carries the information. The advantage of this procedure, from the point of view of the user, is a vastly increased range as well as, under certain circumstances, a degree of secrecy.

It will be shown that whistled languages appear in two main, very different forms. Tone languages, that is those in which pitch characteristics are integral components of the syllable and phonologically significant (i.e., they carry information), when whistled dispense altogether with articulatory features and manifest themselves simply as the transposed-up melodic line of the spoken word. Contrary to all expectations, this drastic pruning does not reduce intelligibility to any marked extent. Non-tonal languages, in which prosodic features play but a subordinate role, keep, at least in a measure, the articulation of ordinary speech. The movements of the tongue, as well as to a slight extent those of the soft palate, imprint a frequency modulation on the carrier, i.e., the whistled tone, so that the *timbre* variations of speech appear in the guise of *pitch* variations. It is not a little surprising that for both types nearly all the parameters of ordinary verbal communication simply vanish with almost no loss of intelligibility, especially in the case of nontonal languages.

The following pages consist largely in an account of the authors' own investigations but the reader will find no shortage of bibliographical material. Various aspects of the subject are described, the emphasis being chiefly on the linguistic, acoustic, ethnic and geographical features. The introductory historical sketch serves primarily to show that whistled languages have a respectable ancestry.

It is hoped that the manner in which the information is presented will make it readily intelligible to the general reader. Even if a few technical details defeat him, this should not seriously interfere with his understanding of the phenomenon as a whole.

August 1976

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A. Classe

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Chapter 1

Introduction and Historical Sketch

In 1948 *Language* published an article by COWAN [25] of the Summer Institute of Linguistics, in which he explained how the Mazateco Indians of Oaxaca, Mexico, communicate both at close quarters and at a distance by means of modulated whistles, with the same ease, speed, and intelligibility as when using speech in the ordinary manner. The account he gave of the technique employed showed it to be a very simple matter indeed. Mazateco is a tone language, that is to say, one in which the fundamental frequency of the glottal waveform, which at the auditory level is associated with the sensation of pitch, plays a role no less important than do the factors of phonation and articulation in all tongues, whether or not these utilize the feature of tone. Now, in the whistled form of Mazateco the sender extracts from all the parameters of the speech continuum the prosodic[1], i.e., musical features of tone and duration, thereby converting the speech signals as we generally know them into a kind of tune that can be whistled and used either as a secret language or as means of communication, with a range greatly in excess of that of the human voice, however stentorian.

This was interesting indeed, but not particularly startling. The most striking aspect of the phenomenon, from the linguistic point of view, was that it emphasized the enormous importance of the tone feature in Mazateco, since the elimination of all but that single parameter appeared to interfere scarcely at all with intelligibility. Cowan pointed out that the same, or similar, procedures had frequently been observed, not only in Central America but also, for example, in Africa where musical instruments such as drums, horns, flutes, etc., are in common use for the purpose of sending messages over considerable distances. These techniques are closely related to that of Mazateco whistle speech, since they are also based on the tone feature of the various languages concerned [30-76].

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[1] In American usage *supra-segmental*.

In 1954 one of the present writers (A.C.) came across an article by the French anthropologist VERNEAU [80] in which he described how the peasants of La Gomera, one of the Canary Islands, converse by means of penetrating whistles over the deep valleys (barrancos) that cross the island radially. Since the language of the Canaries is a dialect of Spanish--not a tone language--the mechanism of the Silbo, as this whistled form of speech is known locally, must necessarily be totally different from that of whistled Mazateco in that it could positively not be based on prosodic features, at least to a significant degree. In a non-tonal language, reliance on intonation, stress and quantity in the absence of articulated speech sounds will clearly not promote ease of communication. Verneau's account was not a little intriguing but his "explanation" based on that of QUEDENFELDT [70] was even more so. Far from throwing any light on the subject he effectually wrapped it in an opaque veil of mystery, as will appear shortly, and it was only after an investigation was carried out on the spot that an explanation, or at least a hint that would have led an alert reader to one, was found to have been supplied by LAJARD in a communication entitled *Le Langage Sifflé des Canaries* [47]. Although his was by no means a scientific treatment of the subject, at least he had a very clear idea of how the Gomero whistle could be used in the way it was since he realized that it was all a matter of articulation, not of prosodic features. Unfortunately his total ignorance of linguistics, and particularly phonetics, prevented his solving the problem and caused him to give a somewhat misleading account of the process. He seems to have thought that the Silbo was a mixture of whistling and normal speech, apparently not realizing that phonation--an indispensable component of normal speech--is incompatible with simultaneous loud whistling and that the approximation of the vocal ligaments necessary for the production of the cord-tone excludes the possibility of emitting air under enough pressure to produce the penetrating sound indispensable for long-distance communication.[2]

A description of the mechanism of the whistled speech will be given in Chapter 5, but it may be stated here and now that in essence it consists in replacing the cord-tone of everyday phonation by a whistle, that is to say, in the case of a steady note, practically a sine wave. This originates at the front end of the speech tract, not in the larynx, the factor of articulation remaining, *mutadis mutandis*, as it is in ordinary speech. Why this explanation did not suggest itself immediately to a professional linguist reading Verneau's or Quedenfeldt's articles is perhaps worth mentioning. If one emits an ordinary lip-whistle, the kind generally used to more or less musical ends, it is not only possible but even relatively easy to articulate almost normally, the chief difference with the movements of ordinary speech being that the lips tend to remain in a fixed rounded position so that labial articulation is impeded and all sounds acquire a constant degree of labialization. Therefore, on the one hand, the resonance-pitch is markedly affected, and on the other labial and labio-dental consonants (p, b, m, f, etc.) are not merely interfered with or modified, but become unpronounceable. In spite of that, anyone who cares to try the experiment will find that if he whistles a sentence (preferably in a phonetically simple language such as Spanish, although this works also, only a little less well, in French or even English, languages phonetically a good deal more complicated), he will probably be understood without much difficulty. The process is after all not essentially different from the whisper-phonation type which also dispenses with the glottal tone, relying as it does on the excitation of the pharyngo-oral cavity resonance by friction of the breath expelled under pressure. ("Not essentially different" should not be taken to mean "to be equated with", for in the whisper, timbre, although subdued, is by no means eliminated). The puzzle was: why did not FRITSCH [32], Quedenfeldt, Verneau and other writers who had been exposed to it, not to mention the many Canarians who do not themselves use it, fail to master the Silbo immediately? In other words, in what significant way did it differ from the common or garden whistle?

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[2] It is, of course, by no means impossible to hum and at the same time emit a rather feeble lip-whistle. One of the writers (A.C.) once heard Sir Richard Paget perform four-part music with his daughter, both simultaneously whistling and humming.

The difficulty of the problem was greatly increased by one paragraph in Verneau's article in which he gave a description of the whistling technique used at La Gomera that was not merely inaccurate but so wide of the mark that it appears to have been drawn from imagination rather than actual observation or even memory, an astonishing state of affairs in view of the fact that Verneau was a trained scientist who had many opportunities of seeing as well as hearing Gomero whistlers. Here is the relevant passage:

> "Pour obtenir cette variété de sons, les insulaires introduisent dans la bouche un doigt de chaque main et ils en modifient la position de diverses manières: les tiennent droits, parfois recourbés. Dans ce prochent; parfois ils tiennent droits, parfois recourbés. Dans ce dernier cas, la convexité peut être tournée en dedans ou en dehors, en haut ou en bas. Si à ces differentes modifications dans la

position des doigts nous ajoutons les lèvres, la langue, le larynx, on comprendra la multitude de sons qui peuvent être émis en sifflant".

This is pure fantasy and one could be forgiven for thinking that the writer had no first-hand knowledge of the Silbo or Silbadores. Whichever technique is favored (the chief ones are described in Chap.4), there is never any movement of the fingers, the lips are kept rigidly motionless, the larynx plays no significant part in the process, the slight groans emitted by some whistlers are inaudible a few yards away and have no influence whatever on the pitch of the whistle. Verneau in fact seems to suggest that whistlers mix up in the course of one emission several techniques which are only possible alternatives. As for the "multitude de sons", this is palpable nonsense. Timbre variations are clearly out of the question, a whistle being to all intents and purposes a simple oscillation that can be varied only in respect of intensity and frequency, i.e., loudness and pitch. In sum, Verneau's description is very misleading for anyone without first-hand experience of the phenomenon. But actual observation of whistlers in action made it clear that their methods of tone production would inevitably result in a signal that could not possibly be immediately intelligible in the way a whisper or even a lip-whistle is. Whichever technique is employed, whether with two fingers, one finger in one of several possible positions, or no finger at all, there must necessarily exist a considerable amount of interference with articulatory movements as compared with the conditions of a labial whistle in which the tongue can function almost as freely as in normal speech. In the Silbo or, for that matter, any other form of articulated whistle used for telecommunication, whether the tongue-tip is applied to the lower incisors with formation of a groove along the antero-posterior axis of the blade (Fig.1), or the blade is kept out of action by the pressure of a finger or two (Figs.2,3,4), the anterior quarter or so of the tongue mass is prevented from changing its position to a significant extent.[3] Attempts at the articulation of front consonants (t, l, n, r, etc.) are frustrated and result exclusively in vertical displacements of the part of the tongue immediately behind the blade. These movements occur because the lingual muscles are only relatively independent of one another, and if one contracts, this tends to induce sympathetic movements of several others. It will be shown in Chapter 5 that this results in the neutralization in all phonetic contexts of numerous significant oppositions always present in

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[3] X-ray films show, however, that at Aas the tip of the tongue retains some freedom and mobility when certain techniques are used, but this is acoustically of no consequence.

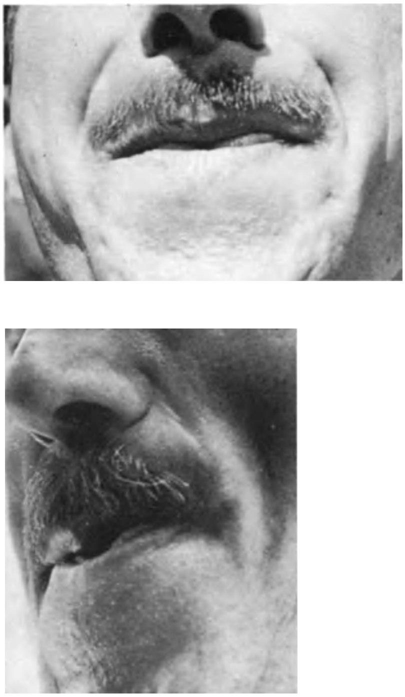

Fig. 1

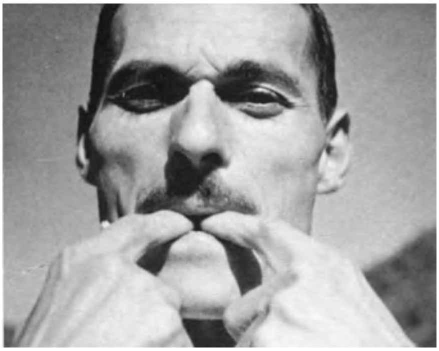

Fig. 2

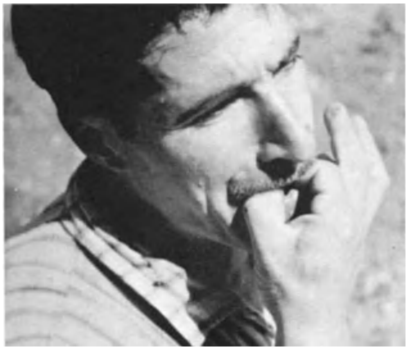

Fig. 3

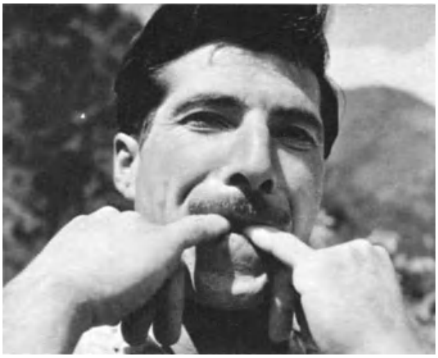

Fig. 4

Fig.1 Turkish whistler, method 1
Fig.2 Turkish whistler, method 2
Fig.3 Turkish whistler using variant of method 2. This variant has not been observed at La Gomera
Fig.4 Turkish whistler, method 2

ordinary speech and possibly preserved in a lip-whistle. This explains why the techniques used at La Gomera, Aas, and Kusköy, of which a description will be found in Chapter 4, are mastered even by native users only after a more or less protracted period of apprenticeship, since the passage from normal to whistled articulation entails modifications to the phonetics, not to mention the phonology of the languages concerned. These presumably contain enough redundancy, not necessarily at the phonological level only, to preserve more than adequate intelligibility, even when numerous oppositions, which were thought to be indispensable for unambiguous communication, have been neutralized.

In view of the fact that the Silbo is a well-known phenomenon in the Canaries, where it is a source of local pride, and is by no means unheard of in Spain,[4] it is rather surprising that nothing about it is to be found in linguistic literature before the *Archivum Linguisticum* article [21]. Elsewhere there are a great many references to it. What is almost certainly the first can be read in a chapter, reproduced here (Fig.5), of *Le Canarien* [7]. Admittedly it is by no means indisputable that "le plus etrange langaige de tous les autres Pais de par deça" refers to a whistled form of speech, nor the "parlent de beaulievres ainsi que fussent sans langue"[5] to its method of production, but in fact all commentators have plumped for that interpretation, perhaps because they could not think of another more plausible one. Of the numerous articles published here and there on the subject of the Silbo, the most important, if only because of their dates (apart from Lajard's valuable contribution referred to above) are FRITSCH [32], QUEDENFELDT [70], and VERNEAU [81,82], who may be said to have started the whole affair, so far as the present writers are concerned. They all describe the Silbo as a picturesque and entertaining phenomenon but throw very little light on its mechanism, Quedenfeldt being the only--much quoted--writer who may be credited with an explanation of sorts, admittedly a signally unhelpful one. His difficulty was that, being no linguist, he failed to evolve any kind of working hypothesis and as a result his well-meant experiment failed to get off the ground. Having, to his credit, observed that the only detectable variable in the medium was pitch, i.e., fundamental frequency, it occurred to him that it was all a matter of prosodic features (although he did not use that terminology), and that suggested to him that musicians would be the best people to test the idea. He enlisted a couple of them who noted, very approximately, what they thought they heard when Gomeros whistled. The accuracy of the transcription was checked by whistling back to other Silbadoes with a success of 0%.

As a control, and without much hope of success, one of the writers whistled the "tunes" noted by Quedenfeldt's musicians to two expert Gomero whistlers,

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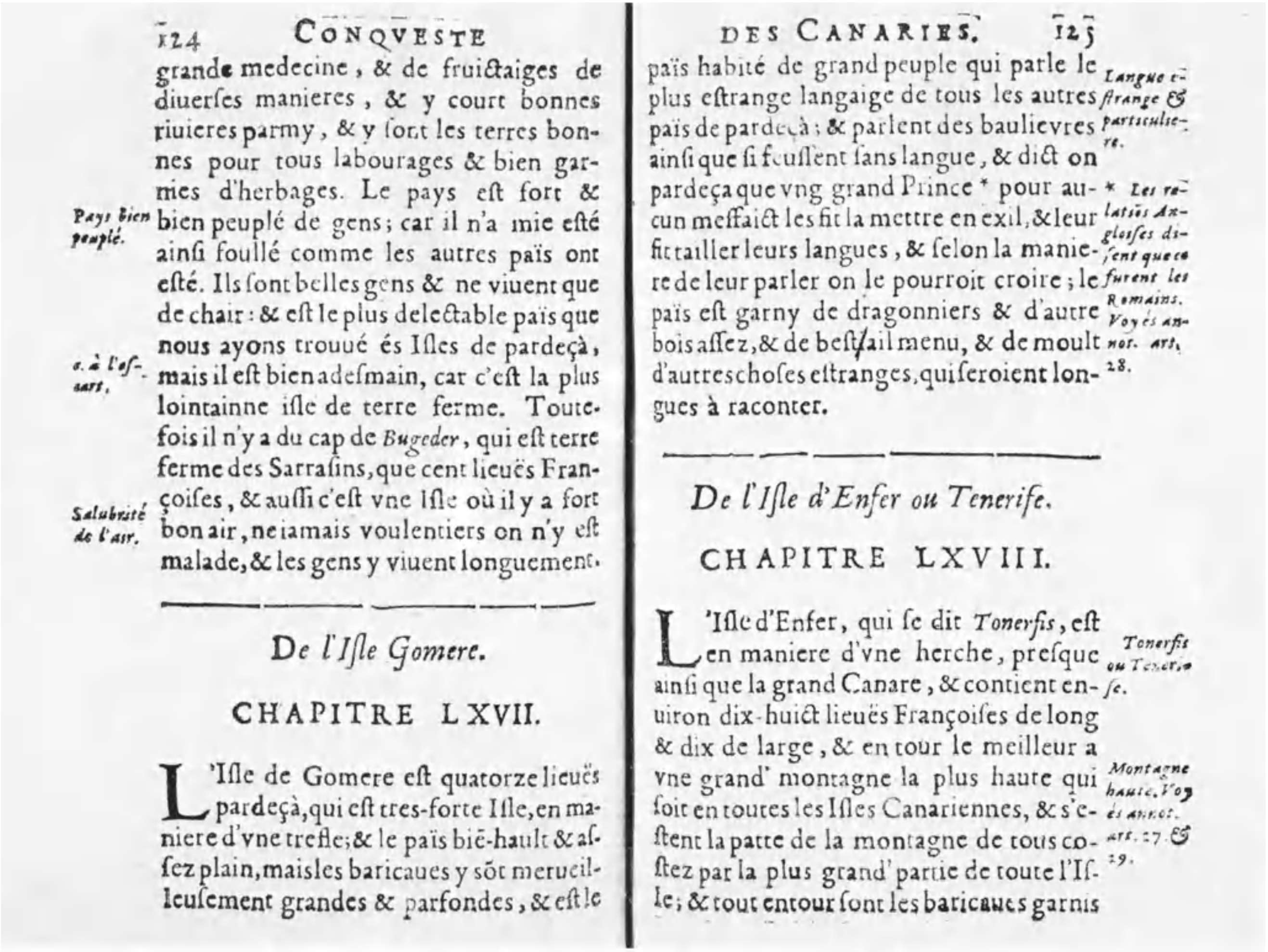
[4] Silbadores were briefly used by both sides during the Spanish Civil War but with performers in opposite camps secrecy was obviously inadequate.

[5] de beaulievres = de bellievres, i.e., with both lips. Bel is related to Latin bis.



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grande medecine, & de fruictaiges de diuerſes manieres, & y court bonnes riuieres parmy, & y ſont les terres bonnes pour tous labourages & bien garnies d'herbages. Le pays eſt fort & bien peuplé de gens; car il n'a mie eſté ainſi foullé comme les autres païs ont eſté. Ils ſont belles gens & ne viuent que de chair: & eſt le plus delectable païs que nous ayons trouué és Iſles de pardeçà, mais il eſt bien adeſmain, car c'eſt la plus lointainne iſle de terre ferme. Toutefois il n'y a du cap de *Bugeder*, qui eſt terre ferme des Sarraſins, que cent lieuës Françoiſes, & auſſi c'eſt vne Iſle où il y a fort bon air, ne iamais voulentiers on n'y eſt malade, & les gens y viuent longuement.

Pays bien peuplé.

o. à l'eſcart,

Salubrité de l'air.

De l'Iſle Gomere.

CHAPITRE LXVII.

L'Iſle de Gomere eſt quatorze lieuës pardeçà, qui eſt tres-forte Iſle, en maniere d'vne trefle; & le païs bié-hault & aſſez plain, mais les baricaues y ſōt merueilleuſement grandes & parfondes, & eſt le

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païs habité de grand peuple qui parle le plus eſtrange langaige de tous les autres païs de pardeçà; & parlent des baulievres ainſi que ſi feuſſent ſans langue, & dict on pardeçà que vng grand Prince * pour aucun meffaict les fit la mettre en exil, & leur fit tailler leurs langues, & ſelon la maniere de leur parler on le pourroit croire; le païs eſt garny de dragonniers & d'autre bois aſſez, & de beſtail menu, & de moult d'autres choſes eſtranges, qui ſeroient longues à raconter.

Langue eſtrange & particuliere.

* *Les relatiõs Angloiſes diſent que ce furent les Romains. Voyés annot. art. 28.*

De l'Iſle d'Enfer ou Tenerife.

CHAPITRE LXVIII.

L'Iſle d'Enfer, qui ſe dit *Tonerfis*, eſt en maniere d'vne herche, preſque ainſi que la grand Canare, & contient enuiron dix-huict lieuës Françoiſes de long & dix de large, & en tour le meilleur a vne grand' montagne la plus haute qui ſoit en toutes les Iſles Canariennes, & s'eſtent la patte de la montagne de tous coſtez par la plus grand' partie de toute l'Iſle; & tout entour ſont les baricaues garnis

Tonerfis ou Tenerife.

Montagne haute. Voyés annot. art. 27. & 29.

Fig.5 Relevant chapter of Bontier and Le Verrier book referred to in the text

Esteban Herrera and María Padilla Sanchez, who at first did not even realize that they were attempts at the Silbo and who, when they did, had a low opinion of them. That the experiment was doomed to failure is seen to be obvious as soon as one remembers that a musician trained along the usual lines in orthodox fashion (and this happened in the last century before Stockhausen and even more advanced composers were dreamed of) would automatically refer any pitch he perceived to the nearest note of the familiar chromatic series. It will be shown later (Chap.5) that apart from the five vowel-phonemes--and even these do not invariably have a fixed or steady pitch--all whistled speech-sound realizations are glides which are interpreted in terms of range, contour, and steepness. It follows that Quedenfeldt's musicians could be expected to produce only notations of vowels "normalized" by being forced into the western musical scale with only the vaguest indications of consonants, if any. This would make the interpretation of their signals by whistlers not merely uncertain but practically impossible. Faced with the vowel series [u a a i a oi] only an abnormally perspicacious reader will immediately recognize it as the sentence "Tu vas a misa hoi?" stripped of its consonants. It is interesting to compare the musicians' version with the genuine article (Fig.6).

Verneau's article did not pass unnoticed and was reproduced in popular magazines, seldom accurately, and often not a little embellished by hack journalists. For example it is the subject of a rather facetious and far from scientific notice in *Le Monde Illustré* [24] (Fig.6). A number of travellers, tourists and others also describe the Silbo with various degrees of inaccuracy; no one, apart from Lajard, seems to have any idea of its mechanics.

One thing, however, is fairly well established, namely its origin. The tradition accepted by many writers as well as the Canarians themselves is that before the conquest of the Canaries by the Spanish expedition led by Jean de Bethencourt, the natives, about whom little can be said that is not speculative, used a whistled form of their language, not only on La Gomera but also on el Hierro, Tenerife, and Gran Canaria. We have no information about Palma, Lanzarote and Fuerteventura.[6] There has been a good deal of speculation about the native language(s) of the Canaries but so little evidence is available

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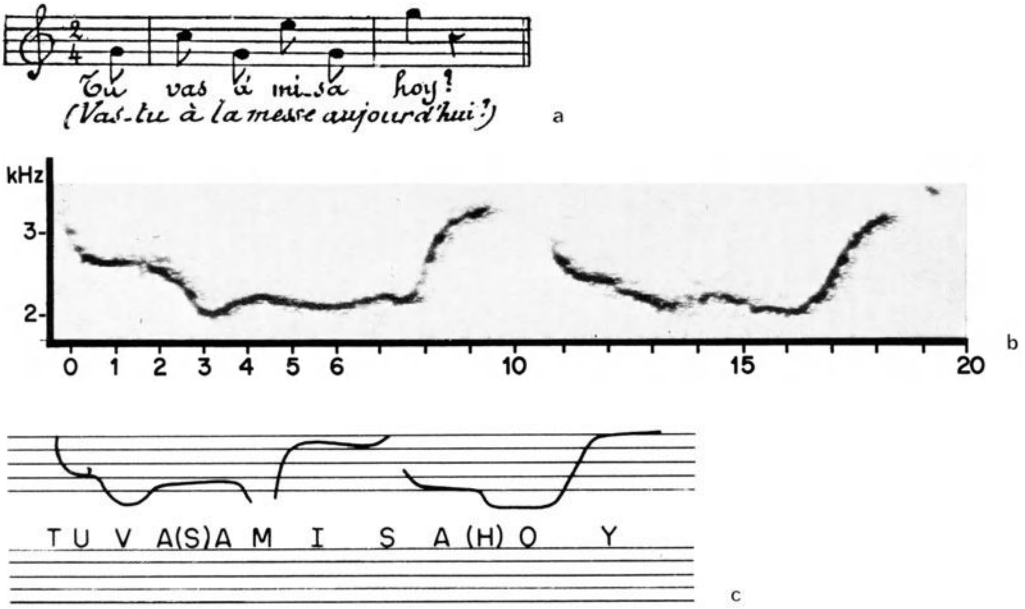
[6] Nowadays only el Hierro still retains slight vestiges of the Silbo; a few names are still whistled, or were in 1956. Yet at the end of the last century it was flourishing, since it is on that island that Lajard learned it sufficiently to whistle some messages, although he never became very proficient at interpreting it.



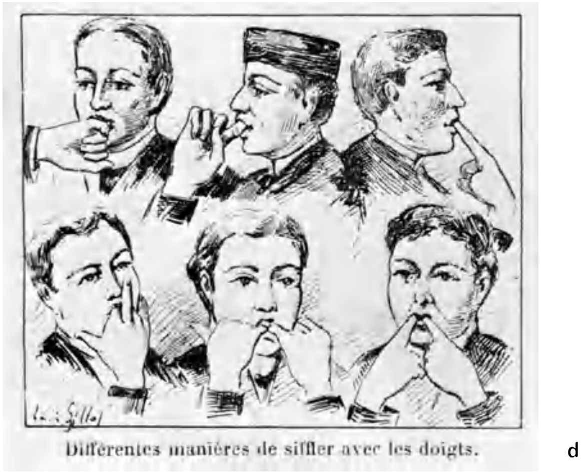

Différentes manières de siffler avec les doigts.
d

Fig.6a-c Gomero: Whistled sentence "¿Tu vas a misa hoy?"
Fig.6d From: Le Monde illustré, 1893

that nothing can be said about it with any confidence. It is clearly difficult to reconstitute a language that has not been in use for some five centuries and of which all that is left are a very few words and a number of geographical names by now thoroughly hispanized. It would seem that the Guanches[7] who survived the war and subsequent wholesale massacre adapted their whistling technique to their conqueror's language which they had perforce to learn. It is presumed that the tongue(s) originally spoken in the archipelago must have had a phonological/phonetic system sufficiently simple to make the whistled version of it as efficient as it appears to have been.[8] That this form of communication has succeeded in surviving to this day is largely due to topographical factors. Even the advent of the telephone on La Gomera has by no means killed the Silbo which continues to serve a useful purpose for the peasants, not only in the hills but also near the coast. The first serious investigation of it and the publication of the *Archivum* article had at least one curious result. After a broadcast on the subject by the ORTF, one of the writers (R.G.B) received from a listener a communication to the effect that what appeared to be a very similar form of communication was to be found, at least vestigially, in the French Pyrenese, in the vicinity of the village of Aas, where the local dialect includes certain Spanish features. The last few users of this French version of the Silbo were approached and their whistling was recorded and duly analyzed. It may be revealed without giving the plot away that it functions exactly like the Silbo Gomero. Then in March 1964 the *New York Times* published a note entitled "Turkish Town Talks in Whistles", in consequence of which an expedition financed by the Wenner-Gren Foundation was organized by Busnel with the object of investigating the phenomenon on the spot. It too was found, not unexpectedly, to function very much like the Silbo Gomero. The results of all three enquiries have been published [13-16, 21-23], and sound films made at Aas and Kusköy are available to certain research and teaching establishments.[9]

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[7] Strictly speaking the name "Guanche" should be applied only to the indigenous inhabitants of Tenerife, but it is customary nowadays to apply the label to all the early populations of the archipelago for the sake of convenience and brevity.

[8] But on this point our ignorance is almost total.

[9] On application to Service du Film Scientifique, 96 Bd. Raspail, 75006 Paris, France.

It will be obvious to anyone listening to the recordings that the character of the three *articulated* whistles is totally different from that of Mazateco, a *tone* type. It will be obvious that Mazateco whistling contains no acoustic feature that could reasonably be attributed to articulatory movements whereas the others evidently do. It is probable that with the aid of the text some portions of the whistled messages would be recognized by anyone with even a rudimentary knowledge of French or Spanish without undue difficulty, in the case of the Gomera and Aas specimens, that is. This would tend to show that learning a whistled form of a language should not be a particularly arduous task for the native speaker of the dialect on which it is based. In the case of the Silbo Gomero one of the main obstacles to ready intelligibility for the non-Canarian is the form of the local Spanish which is a good deal closer to that of Cădiz than of Madrid. In the absence of this particular difficulty the Silbo is readily acquired by local children, and it may well be partly for this reason, as much as because of its undoubted usefulness, that it has succeeded in maintaining itself since its remote, indeed prehistoric, origin.

Now, whereas the Canarian whistle is attested in numerous documents, the history of the Aas whistle is an altogether different matter. The only unquestionable fact is that it is in its last throes and will undoubtedly vanish with the present generation. Already only a handful of middle-aged and elderly people are capable of using it at all and no youth seems acquainted with or even interested in it, unlike Gomeros who display an inordinate pride in their "telêfono". In the Pyrenese, whistling is a dying art and its exponents are not in the virtuoso class of the best Silbadores, perhaps because it is less useful in France than it still is in the Canaries.

At Kusköy, on the other hand, we find a completely different situation in this respect: whistle talk is in daily use. But Kusköy and Aas share one characteristic; as far as could be ascertained, there exists no tradition or written document that could shed some light on the origin or history of the whistle. The only information gathered by the Busnel team was an unverifiable statement to the effect that the whistle was invented and developed less than a hundred years ago, the oldest members of the community asserting categorically that it did not exist in their youth. On the face of it, this strikes one as extremely peculiar, to say the least, but we have no means of discovering at the moment whether it is in fact a recent invention or, alternatively, whether it was created a long time ago, and fell into relative disuse, to be subsequently resurrected. This may be though a somewhat unconvincing hypothesis in view of the ecological factors which are strikingly similar in virtually all respects to those that obtain at La Gomera and, to a lesser extent, Aas. Whistled communication answers the same needs in Turkey as it does in other parts of the world. What seems most strange is that it should have taken such an unconscionable time to stumble upon a device which has been in common use in many parts of the world for so long. However, events with a very low probability, so long as this is not zero, do occur, and it is by no means impossible that the birth of the Kusköy whistle is indeed the recent event its exponents claim.

During recent years other instances of whistled languages have been referred to in linguistic and anthropological literature. COWAN'S interesting article on *Whistled Tepehuan* [26,27] alone lists thirty of them and there are many parts of the world he does not mention. The ones which have been described at all, when they do not approximate to codes or turn out on analysis to be actual codes, seem to belong to one or the other of our two types: tone-based whistles and articulation-based whistles. Other types are of course conceivable.

Chapter 2

Ecology

No matter how the question is approached, we cannot discover any obvious relationship between the various populations which use the whistled languages described here, and one can only conclude that these are either independent inventions or vestigial remains of a proto-historical general phenomenon which has succeeded in surviving under certain geographical and cultural conditions. If this entirely gratuitous hypothesis is not to be rejected out of hand, it is essential in the first place to examine the local conditions in which these populations live and to discover what factors are common to all. This is the subject of this chapter.

The French Population of Aas

In the Pyrenese range of mountains which stretches over some 500 km, the village of Aas is located in the Ossau valley, 120 km or so from the Atlantic coast. It is in what used to be the province of Bearn, near its border with that of La Bigore. Like many high-altitude valleys of the Pyrenese, the Ossau is deeply sunk between steep sides which make communications difficult and effectively isolate populations; this fact, in the past, helped to maintain the integrity of social groups and their independence from the great migration streams which long ago reached these regions of natural barriers that proved so difficult to cross. Aas is situated at an altitude of 750 m, on the left flank of the Ossau valley, which terminates at the Spa of Eaux-Bonnes. The languages spoken by the various populations of that region are Pyrenese dialects--actually, subdialects--all derived from a common Spanish ancestor, through the Bearnais patois, the father of them all. Even if, historically speaking, it proves impossible to demonstrate a direct link between Spain and the natives of this region, it is known that the villages were settled in the 9th century by large numbers of migrants coming originally from the town of Beneharnum, which was razed in 845 by Norman invaders. The town of Lescar now occupies the site. The inhabitants of the Ossau valley exhibit specific characteristics which have interested ethnologists; yet, before the publication of Busnel's monograph in 1962 neither linguists [17,52,66,67,73] nor contemporary

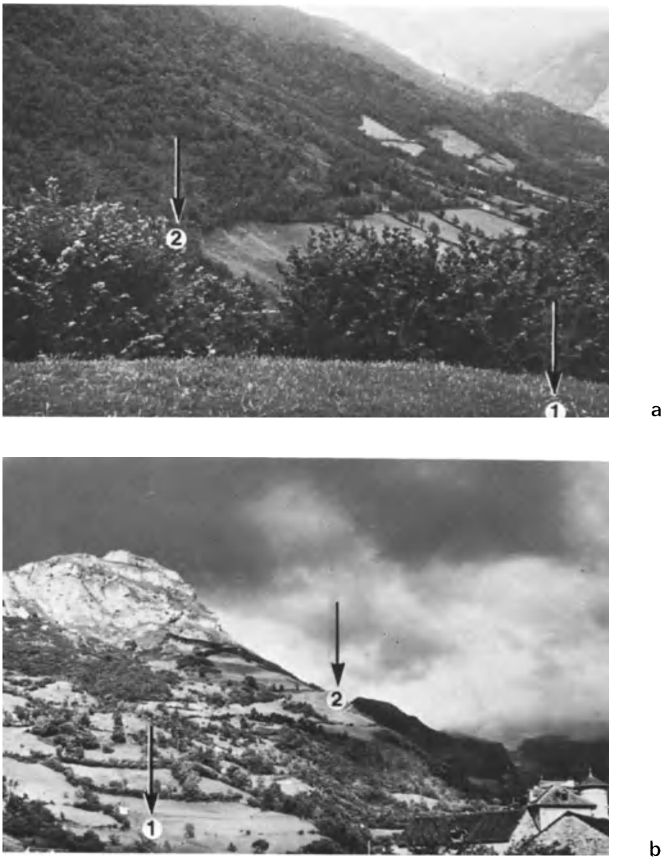
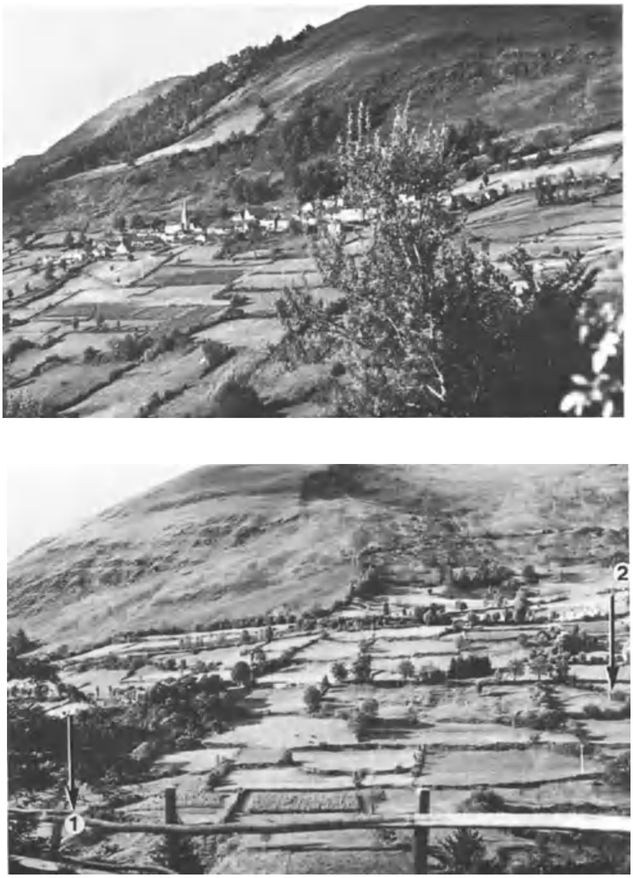


Fig.7a-d Aas landscape: Points marked by arrows indicate the location of whistlers. In every case, the sender was operating from point 1, and listeners were situated at points marked 2-3, etc.

specialists,nor the curators of museums and archives show any sign of being aware of the existence of a whistled language, and no mention of one is to be found in any document. An investigation in depth has shown that the only village in the whole of the French Pyrenese where this phonetic tradition exists is Aas. Nor is there, so far as we can discover, any sign of anything similar in the villages on the Spanish side of the range. Even more remarkably, the inhabitants of neighboring hamlets not only do not use or understand the Aas whistled speech, they seem to be unaware of its existence.

The Situation in 1959 and 1974

In 1959, at the beginning of the enquiry in France, out of 150 villagers, 30 still whistled for the purpose of communication, most of them aged 50 or thereabouts. All had been shepherds in their youth. Whistled speech was used almost exclusively under conditions of isolation in the highlands. Two women who had been shepherdesses in their childhood could still talk in whistles.



c

d

Fig.7c and d

It is said that during the period of shortages in the course of the 1939-1944 war, some farmers who had watered down their milk were caught red-handed, but the police sent to the village to collect evidence drew a blank, for the interested parties, warned by whistled messages, were able to take all necessary precautions in good time.[10]

Changes of occupation, the gradual disappearance of mountain cattle farming, the call of the town--all these factors have led little by little to the depopulation of the mountain and a fall in the number of shepherds. And this as early as 1925. Technical progress and the use of radio receivers, timepieces, tinned food, telegraphy and telephony, binocular and other artifacts, have all contributed to reduce the usefulness of whistled communication, to such an extent that already in 1959 we were dealing with a vestigial language in the process of extinction, one no longer perfectly known to the few remaining users who by then could no longer exploit all its possibilities. We estimate that now only three men can still whistle. Even they can transmit only a few stereotyped messages, chiefly for public demonstrations, broadcasting, etc., a practice of limited scientific interest. This whistled language can then be considered practically extinct.

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[10] Very much the same sort of thing is described by various writers who visited La Gomera during the second half of the last century.

It is clear then that the decay of the system springs from three sociological causes--isolation of individuals, isolation of the social group, pastoral mode of life--and a geographical one--difficulty of covering long distances, which is characteristic of mountainous country. The building of roads, which permits or makes for easier contact between individuals, the increase in the efficiency of communication systems both at the individual and at the group levels through new technologies, and the discontinuance of occupations that tend to maintain the isolation of individuals are the main causes of the decline at Aas of the whistle speech.

The Population of Kusköy, Turkey

In the mountainous region which lies in the northeast of Turkey, very close to the Black Sea coast and some 30 km south of the town of Gorele, a whistled form of Turkish is in use. Its investigation was carried out in the village of Kusköy ("village of the birds", in Turkish). Whistling is in fact used by the whole population of highlanders which is dispersed into no less than 35 villages; the total population was reckoned to be of the order of 25,000 in 1970, scattered over an area of approximately 5,000 km^2. The terrain consists of hills that rise to between 800 and 1200 m, their steep sides forming deep and generally narrow valleys. The landscape closely resembles that of the Pyrenese and of Mexico (Fig.9). The barrancos of La Gomera, although possessing their own characteristic features, belong to the same topographical type. One of the consequences of the ground configuration is that it makes moving about very difficult. There are practically no roads adapted to wheeled transport, and the winding paths make travelling on foot slow and laborious. Another important feature is the scattering of dwelling houses in the hills, the result of the cultivation of crops on terraces forming successions of levels. Halfway up the slope, hamlets and villages cling to the flanks of valleys, and, rather than the concentration of inhabitants characteristic of

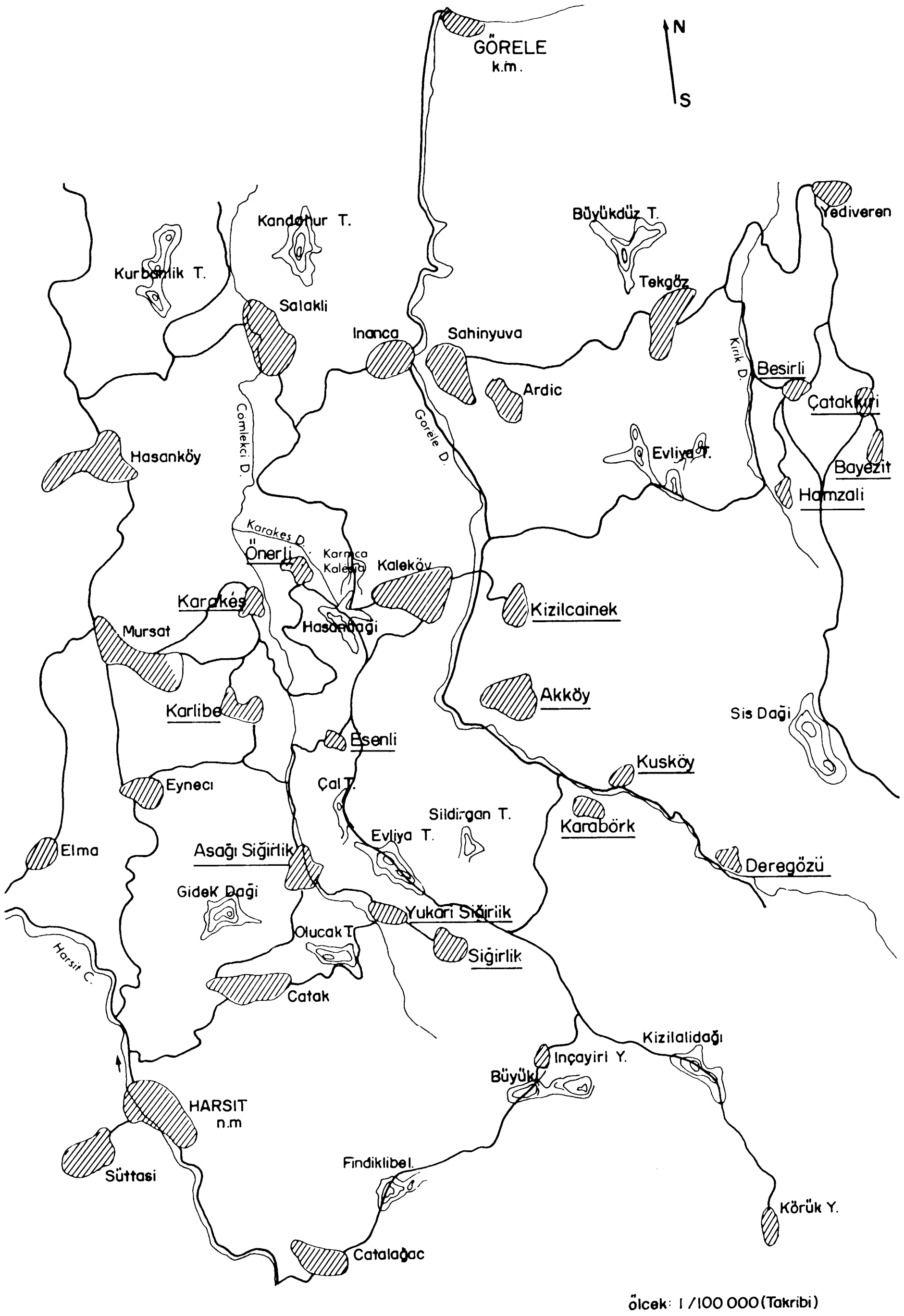
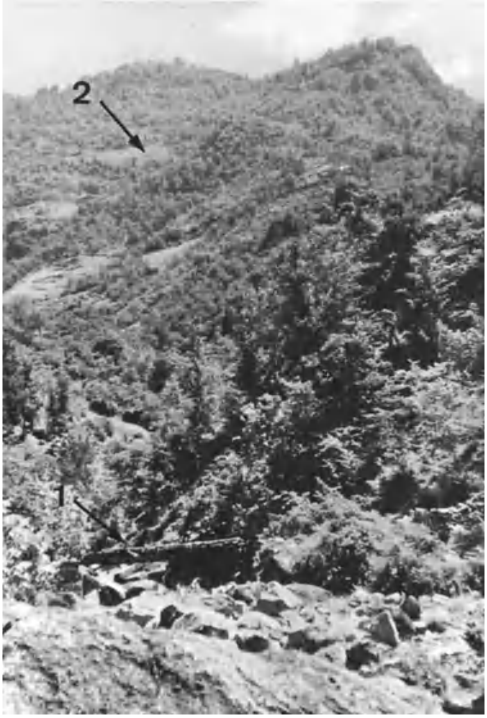
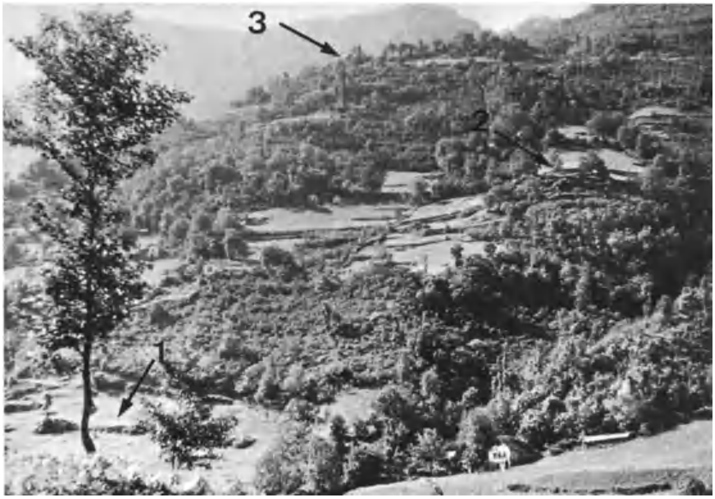


Fig.8 Map of Kusköy



a



b

Fig.9a-d Kusköy landscape: Points marked by arrows indicate the location of whistlers. In every case, the sender was operating from point 1 and listeners were situated at points marked 2-3, etc.

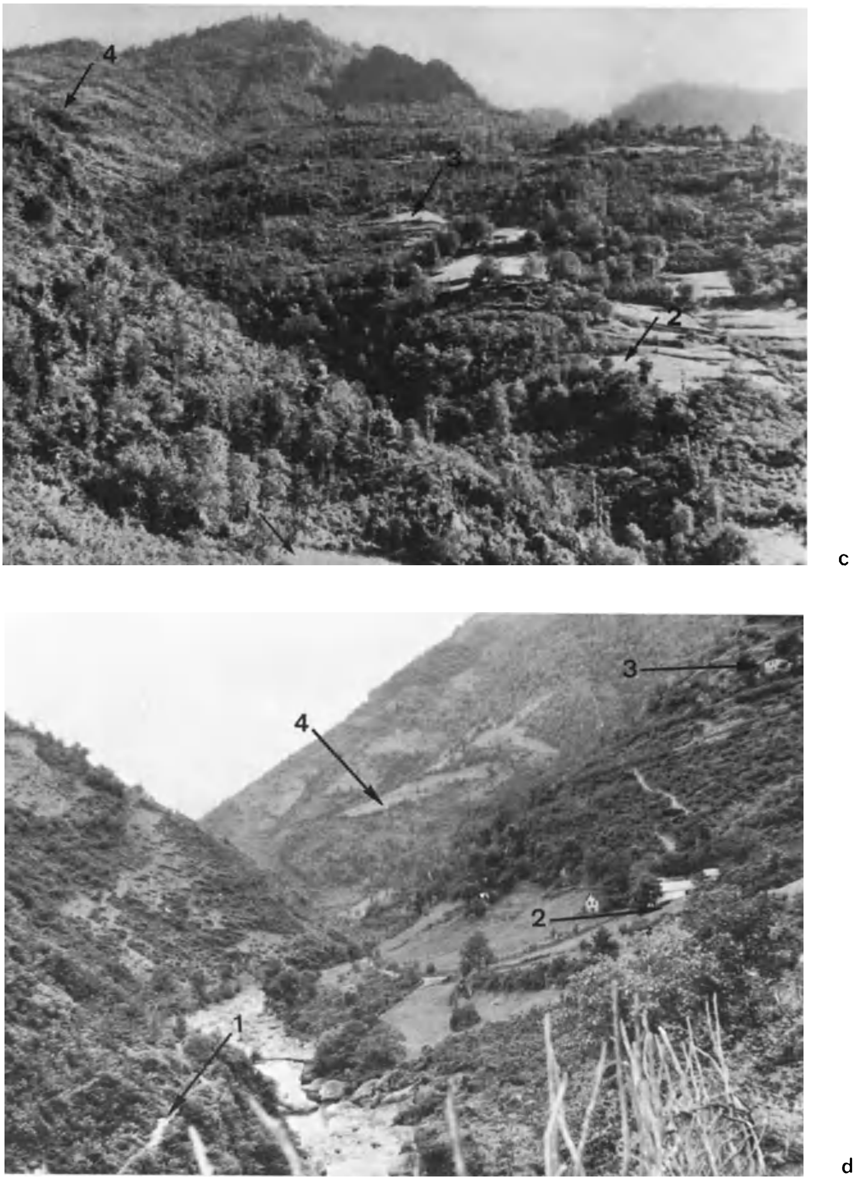


Fig.9c and d

plain civilizations, we find loose groupings of houses sprawling over several kilometers. At Kusköy for example there were in 1969, some 500 inhabitants distributed in 85 dwellings spread over 2.5 km. These ecological conditions compel families to be more or less self-sufficient; there is no commerce to speak of in these villages. The nearest "trading center" is the large village of Canakci, ten kilometers from Kusköy. Here, as elsewhere, geographical isolation combined with mountainous topography is associated with the use of a whistled form of speech.

Present Status of Whistled Speech at Kusköy (1970)

The whole population uses whistling for the purpose of long-distance communication. As elsewhere, elderly people can have problems with their dentition (loss of teeth in later life)[11] and children who have lost their milk teeth and not yet acquired their adult set are unable to whistle for mechanical reasons. Learning to whistle is part of the standard social conditioning in the context of the family precisely as is the acquisition of ordinary speech. Children who can speak by the time they are three or four understand the whistled speech by the age of five or six. They are beginning to use it actively around the age of twelve but become fully proficient only when they are in posession of their adult teeth, that is to say when they can produce a loud and fully controlled whistle. Although some children receive from grown-ups some instruction regarding the finger position, most are essentially self-taught, although they help one another by correcting mistakes when the message is unintelligible or unclear. This learning process takes place chiefly while the children are looking after animals on the heights and must communicate over considerable distances because of their isolation. Since the work of shepherds is performed by children of either sex, they almost all learn to whistle. There are, in some villages, a few people who cannot use the whistled language; on enquiry it turned out they never were shepherds.

It must be emphasized that the whistle is a medium of communication, never to be thought of as a game or an entertainment. But, since it fulfills all the functions of speech, its use does not exclude puns, plays on words and kindred verbal performances. A similar situation obtains at La Gomera and in Mexico where the whistled language is used almost exclusively by the peasant class, that is to say, by people to whom it is really useful. However it must be said that at San Sebastiãn de la Gomera several people of the "upper class"--one medical practitioner, one land-owner, a bank manager's daughter, and a schoolmaster among others--understood the Silbo and at least one of them was an efficient performer.

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[11] Few even quite old people at La Gomera seemed to have lost their teeth. It is presumably a question of diet.

It is worth mentioning that, as appeared in the course of the enquiry, the evaluation of a whistler's performance never includes aesthetic considerations. In the Turkish villages where only a few people can use the technique, a distinction is generally made between those who communicate better and farther and those who do it less well and less far. But where the whole population is proficient in the art, as at Kusköy, this kind of distinction is never made; all whistle equally well and are capable of sending all sorts of messages over comparable distances. It may well be that this reflects a degree of mistrust towards the enquirers. (These remarks are not quite so universally true at La Gomera, perhaps because whistlers and non-whistlers are to be found more or less everywhere; but particularly efficient whistlers are often distinguished by more or less picturesque nicknames. For example, at the very edge of San Sebastiãn, a young man renowned for the excellence of his performance was called "El Pãjarito" and at Santa Catalina one whistler was refered to as "El Campeõn" because of the extraordinary clarity and stupendous power of his whistling).

Among the various villages that appear on the map there are some where the whistled language is totally unknown. It did not prove possible to obtain any information regarding their history, but it is conceivable that they were settled by non-autochtonous people superimposed upon groups that were already occupying the country.

One may wonder under what conditions the whistled language is used in preference to ordinary speech. The short answer is whenever the latter is inadequate, and then whistled language is invariably used, in the most diverse contexts. Any concept, commonplace or extraordinary, can be communicated, so long as the lexis of the whistler includes a sign for it. This preference for a whistled signal is readily intelligible. Although it is possible to produce almost as many decibels with a yell as with a whistle (100 or more), articulation lowers that level considerably in the case of speech, and hardly at all in a whistle. It is then merely an example of the principle of least effort. Quite naturally the whistle is used by interlocutors placed in the same valley at two points two hours' walk distant. In a straight line, this man mean only 2300 m at the most and in some places, for instance at La Gomera, whistled communications take place over distances greatly in excess of that figure because of geological features which seem peculiar to that island. From these considerations it is clear that whistled speech will be most useful in connection with pastoral and agricultural activities and will serve to call someone, give an order or draw his attention to an unusual situation, etc. It will also be used to give news of social events, whether collective or personal, of reunions, accidents, illnesses, births. And, at La Gomera, shepherds were observed whiling away the long day by conversing with each other in this fashion.

Not unexpectedly such a form of communication, for those who cannot use it themselves or are ignorant of its existence, has its "secret language" side.[12] At Aas, for example, we met instances of situations involving natives and "foreigners". The coming of officials whose mission was to make a census of cattle for tax purposes, or to control tree felling, was signalled from village to village and to the remotest spots by whistlers who relayed the information so that control could be evaded. One can hear locally any number of anecdotes which illustrate amusingly the usefulness of the whistled language. (Exactly the same situation existed at La Gomera until the island reluctantly acquired its own police force, Customs officers, etc.).

The 1964 enquiry has unfortunately provided no precise information regarding the history of the whistled language, which is known locally as the "language of the birds". The oldest inhabitants who in 1964 were between 75 and 80 years of age, asserted that in their youth it did not exist in its present form, that around 1900-1910 it was used exclusively for controlling animals, and that the present-day whistled language grew out of that. In view of the difficulties that beset that kind of enquiry, we cannot unreservedly either endorse or reject this account, which was given only incidentally. Although at the time of the enquiry the whistled language of Kusköy was flourishing, we are of the opinion that within two or three generations we shall witness at Kusköy the extinction of language like the one that happened at Aas, and that which is threatening in Mexico and the Canaries. The building of roads, the exodus from the countryside, already noticeable in 1966, when a number of young men were attracted by the high wages to be earned in the industrialized countries of Western Europe, in particular Germany and Switzerland, will prove to be here as elsewhere the cause of an evolution that will toll the knell of the Turkish whistled language.

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[12] A whistled form of speech seems to have been used as a secret language by ñañigos (members of a secret society that terrorized Cuba when it was still under Spanish rule).

Table 1 gives a list of villages where the whistle language is in use.

Table 1 Alphabetic list of villages in the Kusköy region where the whistled language is in use

Akköy
Asaḡisiḡirlik
Alagavur
Artvin
Besirli
Bayezit
Bakimli
Cimide
Catakkiri
Deregözü
Dorukgeris
Doḡanci
Esenli
Ege
Giresun
Gümüshane
Hamzali
Karlibel
Kusköy
Karabörk
Kabasakal
Kizilcinek
Kizilca Inek
Kerete
Kösebek
Önerli
Peyecukur
Rize
Simenne
Siḡirlik
Tepeaḡiz
Trabzon
Yukari Siḡirlik

La Gomera

La Gomera is one of the Canary Islands, lying in the Atlantic off the west coast of North Africa. Its population of some 35,000 Spanish-speaking people is scattered over the island in many tiny hamlets and four very small towns. Volcanic in origin, it is remarkable for an exceedingly rugged and peculiar topography (Fig.10). In shape it is very much like a large tent. From the central peak, the Alto de Garajonay, some 1500 m high, it slopes down on all sides to sheer cliffs at the sea edge. Deep gorges radiating from the center cut up the terrain. It is difficult mountain country where two points only 500 yards apart as the crow flies may easily be as much as an hour apart in walking time (Fig.11). With the exception of one single road built comparatively recently which links the capital San Sebastiân with the other towns, the only means of travel between most points is a number of goat tracks which are often no easier than the average Alpine path. Clearly communication poses no small problems even if in 1972 the situation was slightly better than in 1956. The ecological situation of El Hierro was much the same as it was about 1860, at the time of Lajard's visit, when he found whistlers there, as well as some vague traces of them on Gran Canaria. We (A.C.) could find no whistler on either island and in 1972 even the number of Gomero whistlers was probably decreasing. But because crossing a barranco still means a hard trudge, the Silbo which supplies an easy and efficient mode of communication survives whereas, it has vanished from the other six islands of the group where, according to tradition, it once flourished.

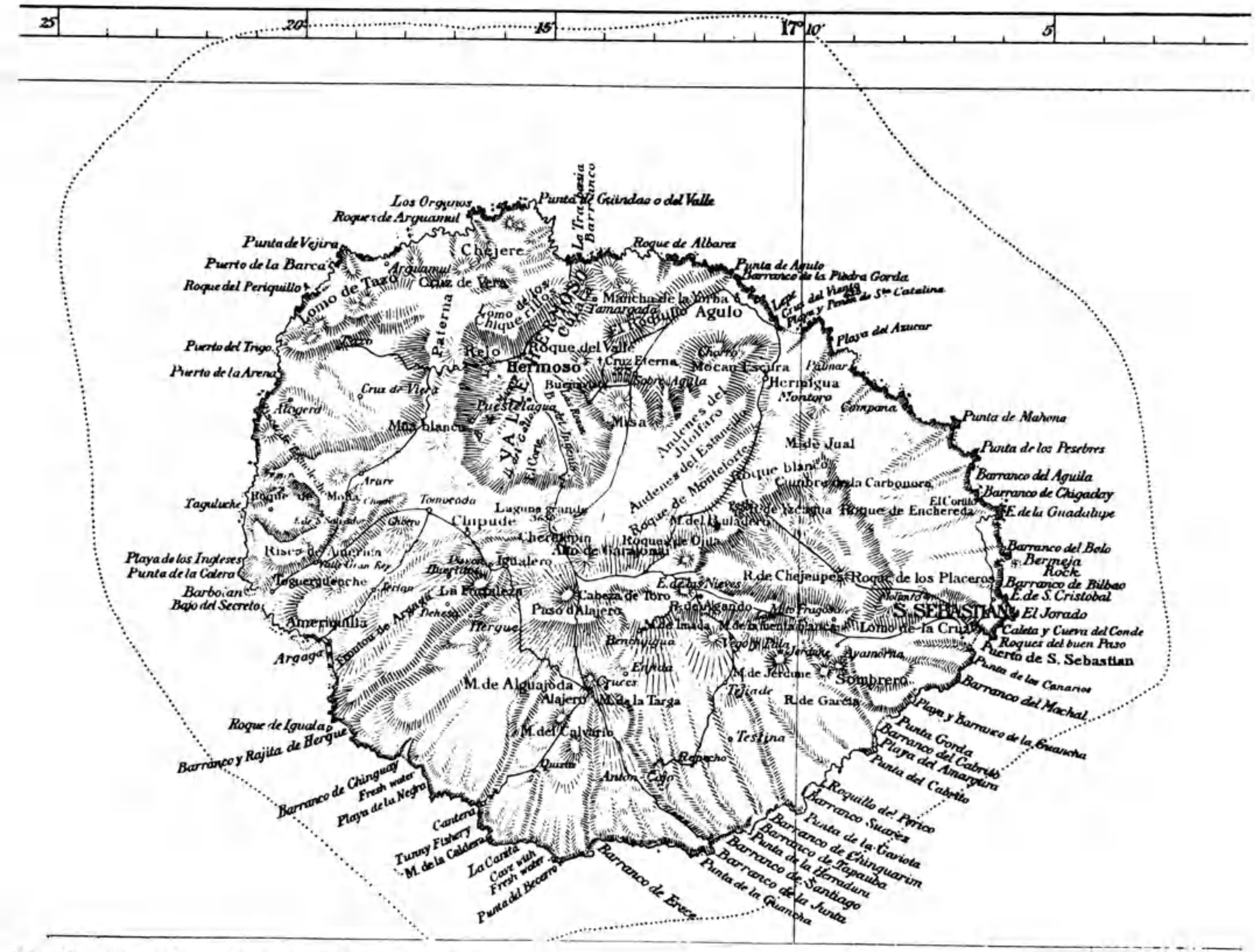

Fig.10 Map of La Gomera (17 x 17 miles)

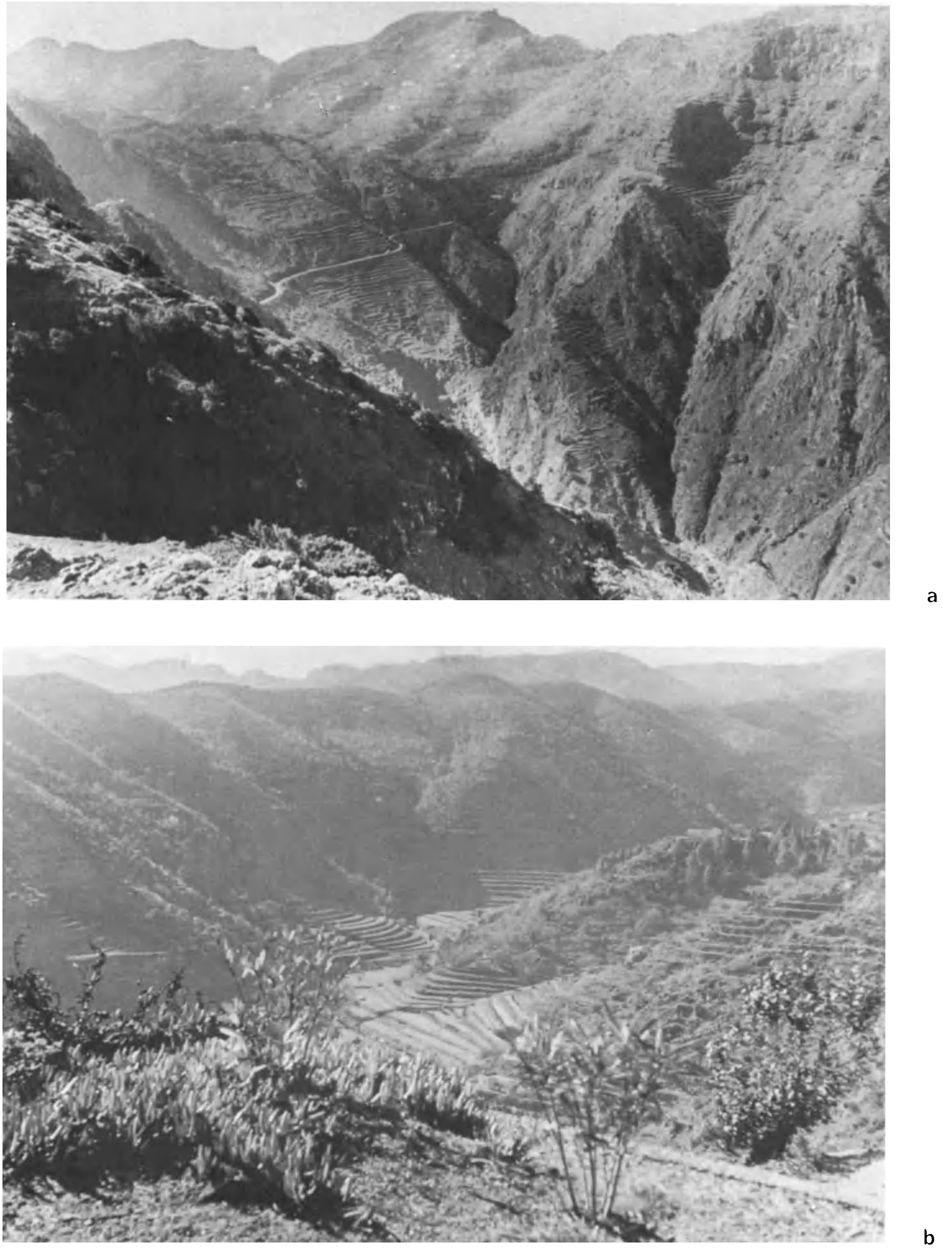

Fig.11a and b La Gomera landscape above Agulo

The Mazateco Population

The whistled speech of the Mazateco Indians of the state of Oaxaca, Mexico, was initially described by COWAN [25] in 1948. His work was of major importance, drawing as it did the attention of the scientific world to a largely unknown mode of communication, although, as mentioned above, the existence of the phenomenon had been publicized by a number of writers at the end of the last century [24,47,70], and seems to have been referred to as far back as the 15th century [7]. The Mazatecos occupy a region situated approximately in a triangle formed by Oaxaca in the south, Tierra Blanca, and Tehuacan, its main

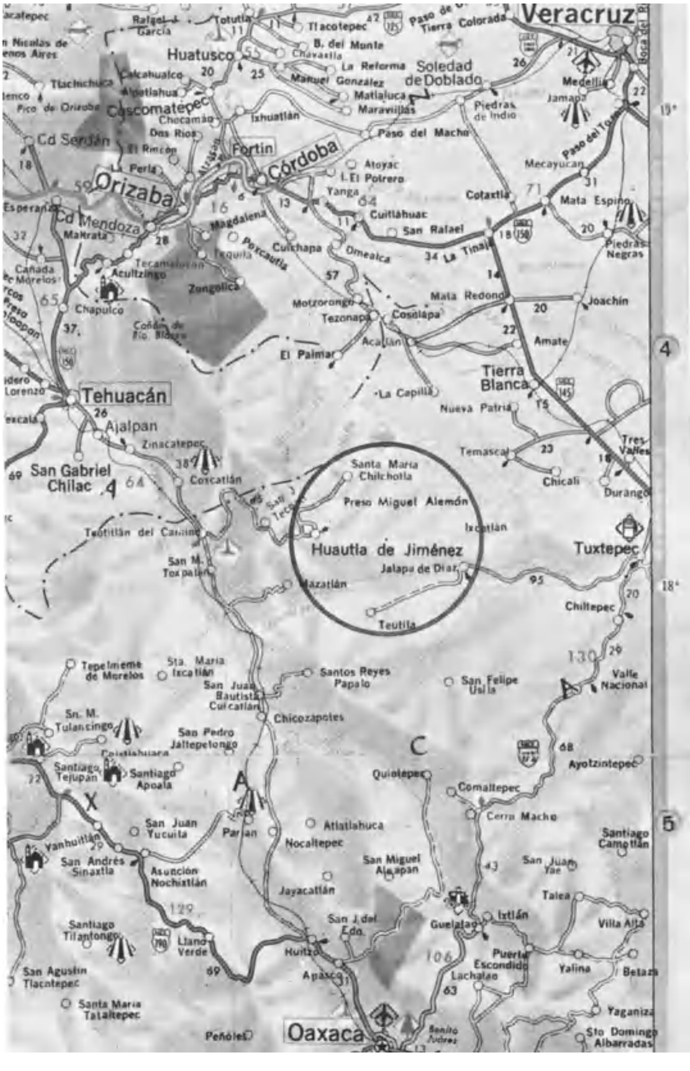

Fig.12 Map of the Mazateco country in Mexico. The circle marks the region where the investigation was carried out

center being Huautla de Jemēnez (see map, Fig.12). According to official data, the 1970 census put the population figure at 124,000. The main part of our (R.-G.B.) 1972 investigation was centered on the Teotilan del Camino district; it is in the Sierra Mazateca which covers an area of 1200 km^2. Huaulta is 84 km from Teotitlan. In that zone the hills reach an average height of 2500 m with three peaks 2700 and 2988 m high. The 1970 census gave a figure of 92,500 inhabitants for the Sierra Mazateca alone. This is mountain country, crossed by more or less narrow valleys, on the whole less narrow than those of La Gomera, Aas, and Turkey (Fig.13). One generally distinguishes between the lowlands, formed by the bottom of the valleys, in the region of the Tamascal barrage, to the northeast of Huautla, and the highlands where the villages may be found at an altitude of 1000 to 1200 m. According to local authorities one can also find in these Mazateco regions mixed populations (e.g., Coarzospan) and villages where other languages are spoken: Nahuatl (for example in the Huautla district, San Barbardino, Santa Marīa Teopoxco, Vigastepec) or Chinanteco, where no whistled form of the language is to be heard. We ourselves stayed at Huautla (alt. 1750 m), at San Mateo Eloxochitlan, Santa Marīa Chiltchotla, and Tenango (alt. 1000 m). Like the other regions we investigated before, the Mazateco country possesses characteristics which seem always to be found where whistled languages are used:

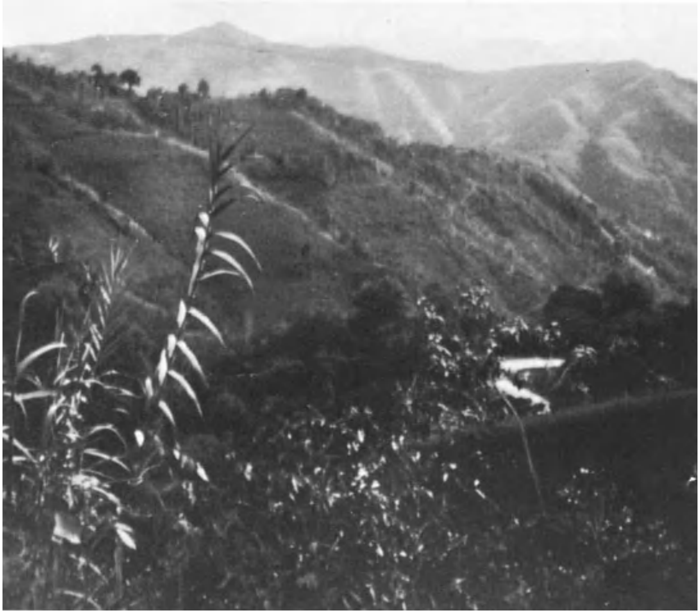

Fig.13 Mazateco landscape near Huautla de Jimēnez

an abrupt relief associated with mountainous landscapes, slow and difficult communications, scattered settlements, cultivation of hillsides, often far from the villages. These ecological features, common to the four regions we have observed, seem to constitute at least one of the necessary conditions of the existence of whistled communication systems, if not of their invention through necessity, the starting point being that the inventors must have noticed the possibility of utilizing the relief as wave guides for the propagation of signals over long distances.

However, one important fact peculiar to Mazateco country must be emphasized: the vegetation is considerably denser than in the other regions where we have observed whistled forms of language, at least at the bottom of the valleys, and these are less deep and narrow than say at La Gomera or Aas. It can be deduced from these facts that from the physical point of view conditions are not nearly so good as they are for example at Kusköy or Chipude, where slopes are extremely steep and barrancos narrow. However, even in Mazateco country, it is quite possible for whistles to carry at least 2000 m. Yet, rather surprisingly, information from whistlers reveals that they are in general used only for conversation over short distances, of the order of a few hundred meters. Here are some values supplied by informants from sundry villages: San Mareo, 100 to 200 m; Santa María, 500 m, 400-500 m; Tenango, 500 m; from Piedra Negra to the village, 500 m. One is therefore led to think that whistling is done only exceptionally at high levels and has to some extent fallen into disuse. The explanation is not difficult to find. In order to produce the decibels necessary for long-distance communication the use of finger techniques or of the fingerless method described in Chapter 4 is essential, and none of the informants was acquainted with them; they all used a lip-whistle (Fig.14). They seemed surprised when presented with pictures of Gomero and French whistlers. Only one Mazateco remembered having used a finger technique to whistle loudly in his youth, and for amusement only, not for proper communication. Short distances, then, and a *lip*-whistle may be said to distinguish the Mazateco whistled language from the others. If long-distance communication becomes essential, as in the case of municipal collective work (FAENA), the transmitter, as we witnessed at Tenango, uses a shell and the signal then has a range of 8 to 10 km in rocky valleys, but in this case we are dealing with a code that bears no relation to the whistled language. Nevertheless this practice demonstrates that the physical properties of the wave guide are still available, and the distance limitations

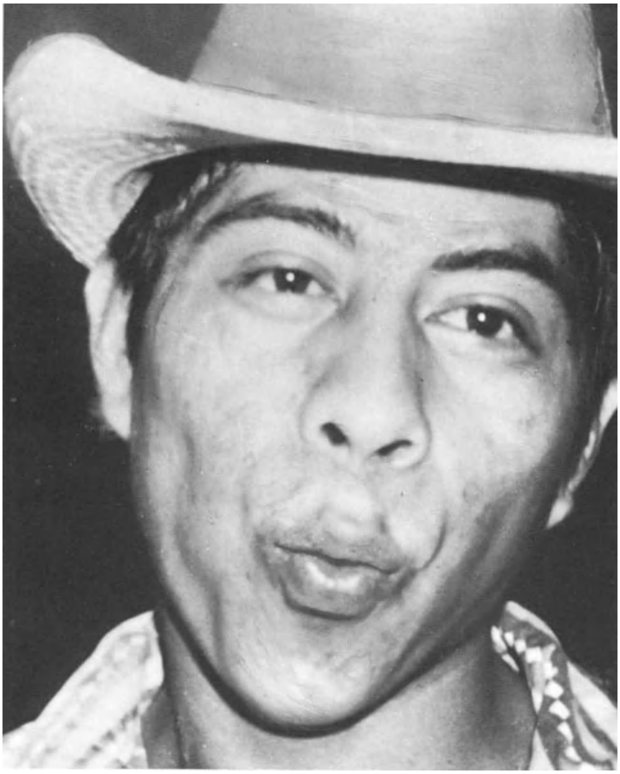

Fig.14 Mazateco whistler, bi-labial whistle

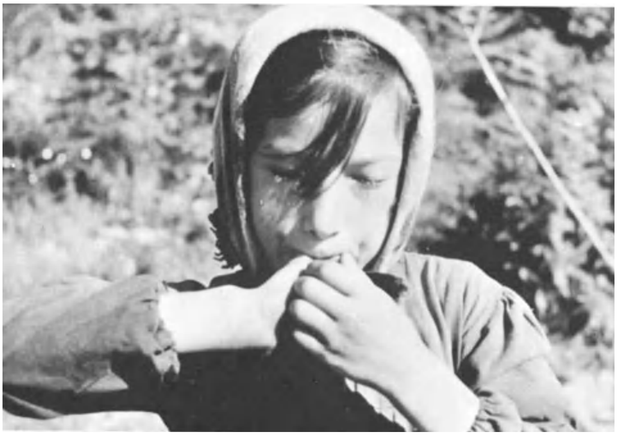

Fig.15 Turkish girl, whistling by method 3 d

of the whistled language in this case are a sociological, not a technical nature.

Perhaps the most striking feature of the Mazateco whistle-speech is its frequent use at close quarters, as pointed out by Cowan. For example, in a group of Indians in the marketplace, two may be observed conversing in whistles while the others are using ordinary speech. At La Gomera, Aas or Kusköy this kind of thing would never happen. On the one occasion when two whistlers at La Dama (La Gomera) conversed with each other when they were only a few yards apart for the benefit of admiring foreign witnesses, the native audience obviously thought it was a huge joke and the most unnatural kind of performance. Except in Mexico, the whistle language serves the purpose of telecommunication exclusively. Since the correct physical conditions exist in Mazateco country as they do elsewhere, the only plausible explanation of this state of affairs must almost necessarily be that it is the result of social conditions (work in groups, for example). These might perhaps be worth investigating more closely. Another important fact is the absence of herds of animals and, as a result, of isolated shepherds or cowherds who, in other parts of the world, may well have been the inventors, and are undoubtedly the most frequent users of the system. These circumstances may well account for the non-use of the various digital techniques which are practically unknown here.

Cowan points out that Mazateco women do not whistle whereas elsewhere female whistlers are as numerous as male ones (Fig.15). In fact, in Mexico, *children* of both sexes do whistle and only the social position of adult women seems to rule out the practice in that particular local civilization. In all the other countries visited we invariably found many women who were as capable performers as the men.

We obtained some information from Mazateco whistlers regarding the possibilities of identification and informative criteria, but it did not prove possible to test their assertions experimentally as we had done in Turkey. For instance, according to them, they were able to tell the approximate age and the sex of an unseen whistler, and to a certain extent the humor he was in. Dialectal variations could be analyzed only partly in whistled speech, and when they could it was a matter of vocabulary, not of tones. According to them, the whistler's identity could be determined only with great difficulty, if at all.

As in other parts of the world investigated by us, learning to whistle begins after the acquisition of the spoken language, and comprehension precedes actual performance (about 6-7). The role played by the teeth is well understood. It may be mentioned by the way that some bilingual informants

(Mazateco-Spanish) could whistle in Spanish as well. However we must emphasize that we failed to obtain any sign of understanding from them when they listened to Gomero and Aas recordings, whereas at La Gomera we did get positive results with whistled Turkish or French, at the phonetic level only, of course. The implications of these facts are briefly discussed in Chapter 5.

Chapter 3

Physics of the Signal; Range

All whistled languages share one basic characteristic: they function by varying the frequency of a simple wave-form as a function of time, generally with minimal dynamic variations (but see COWAN [25]), which is readily understandable since in most cases their only purpose is long-distance communication. An exception is a language like Mazateco which is often whistled even for close-quarter exchanges and which exhibits dynamic variations and consequently should be capable of carrying non-verbal information as well as the basic message, but this aspect of the question has not yet been studied experimentally.

The analysis of whistle language spectra by means of various instruments (Sonagraph or similar, or correlator) shows that the signal consists of a pure frequency plus 1, 2, or 3 weak harmonics. These, it must be stressed, bear no relation to speech formants and carry no information whatever. Some are the byproducts of overloading in the course of recording; others are produced by the analyzer itself, especially in the case of the spectrograph. In any case, relatively to the fundamentals they are extremely feeble and their carrying power is in no way comparable to that of the main frequency. The range of frequency is very similar for the various whistled languages as the following figures demonstrate.

	Gomera	Aas	Kusköy	Mazateco
Frequency in Hz	1200-2500	1200-2600	1500-2500	1400-2500
Maximum frequency	3500	3500	4000	2700

It must be pointed out that this particular physical characteristic is of interest only insofar as it shows the mean pitch to be located in the region of 2 kHz, that is to say within the band of maximum sensitivity of the ear--because of the resonance characteristics of the auditory tract--and also because it is above the frequency spectrum of maximum amplitude of natural background noise. Whereas in the whistled form of a non-tonal language the extreme frequency range can exceed two octaves (1.2 to 3.5 kHz at La Gomera and Aas, 1.4 to 4 kHz at Kusköy), the range of a whistled tone language,

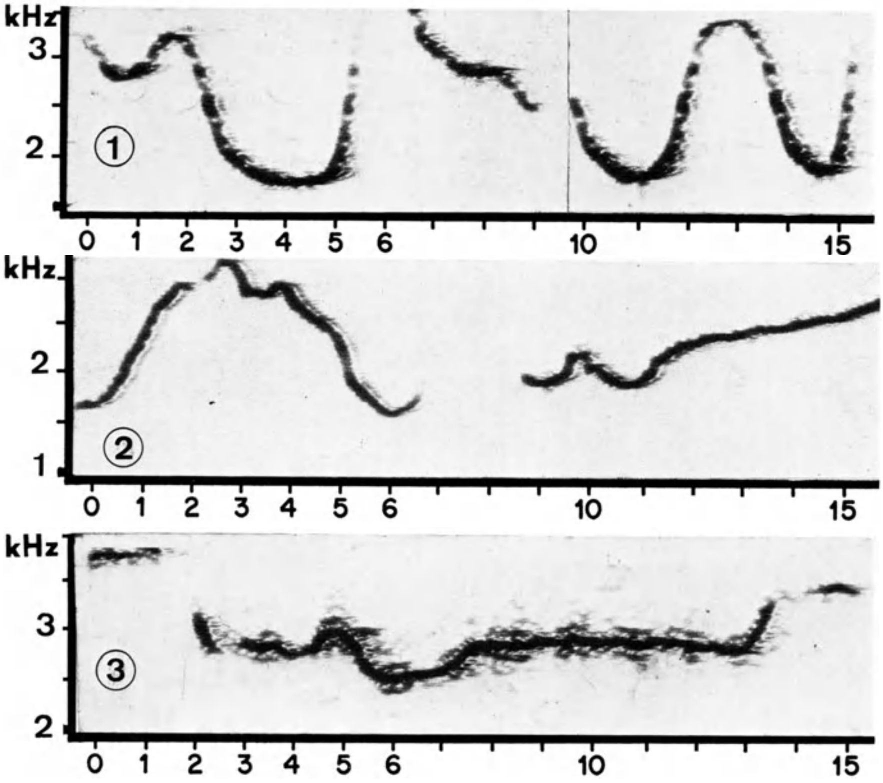

Fig.16 Three sonagrams showing range of frequencies in whistle. 1: Kusköy; 2: Gomera; 3: Aas

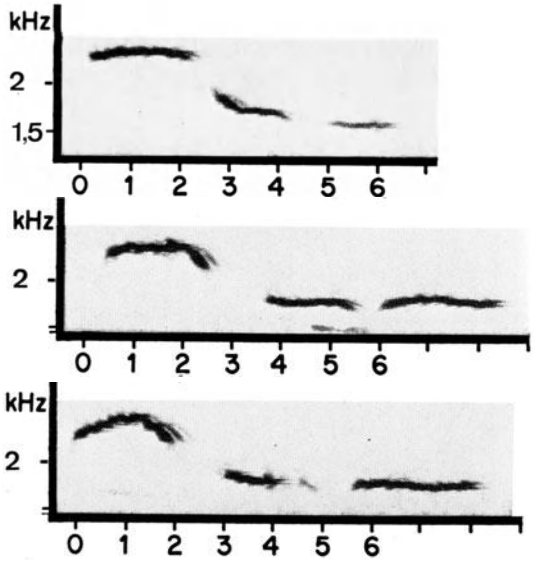

Fig.17 Mazateco: TCHAO-NI-HI (from top to bottom):
short-distance whistling
mid-distance whistling
long-distance whistling

duplicating as it does that of speech, is narrower, the observed limits being 1.4 and 2.7 kHz in the case of Mazateco, that is to say just under one octave. In many cases it does not exceed 500 Hz (Fig.17), and the compass of the whistle is clearly comparable to that of the fundamental frequency of the spoken word, which determines the tone.

Intensity is of necessity associated with distance. We have mentioned the considerable differences which exist between the various whistled languages as regards the distances over which they are used normally. It is hardly surprising then that the dynamic levels of whistled Mazateco should be comparable to those of speech or slightly less (60 to 80 dB) and should vary in the same way. Only in exceptional circumstances do we find higher values (100 dB) as in the case of whistling with a leaf (see Chap.4). Naturally a given whistler's frequency range varies somewhat according to the distance involved, and also to the whistling technique used. Recordings of two Mazateco performers each emitting the same signal three times for short, medium and long distances were analyzed by means of a correlator (for Fourier transform, see Fig.18). We thus obtained for each series an integrated spectrum statistically analyzable. The test word was tchao-ni-hi [tʃaonihi] (ear of corn, *totomosle* in Mazateco Spanish). Fig.18 shows the curves for the two whistlers and the other tracings relate to Gomero and Turkish spectra, given for the sake of comparison. We obtained the following values in Hz for the frequencies of maximum amplitude:

	Whistler A	Whistler B	
1.	1516, 2450	1583, 2283	long distance, forte
2.	1450, 2300	1766, 2316	short distance, piano
3.	1583, 2645	1850, 2533	medium distance, mezzo forte

Spectrum differences are equal to or greater than 3% and easily heard. Such differences are significant in the spoken form of tone languages. This confirms, as could have been expected, that absolute frequency values are irrelevant and that only relative pitches matter. This is the reason why one can, in the conversion of the spoken tone into whistled tone, transpose the melody up by three octaves or more without interfering with intelligibility. It will have been noticed, incidentally, that both informants make use of a somewhat higher frequency band for medium distances than for long or short. This is difficult to account for.

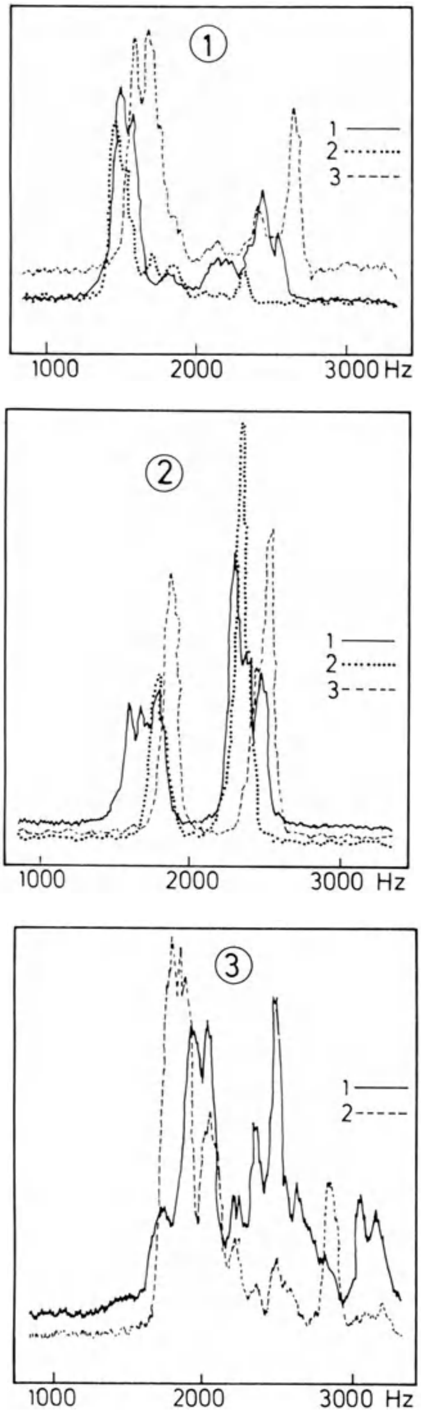

Fig.18 $R_1 - R_2 - R_3$ = spectrum analysis with correlator and the Fourier transform for Mazateco (1-2). Long (1) short (2) and medium (3) distances. Two whistlers: (3-1): Turkish; (3-2): Gomero

Propagation of the Signal in Natural Surroundings

The linguistic aspect of the whistled signal is not the only interesting one. It is worth looking at also from the point of view of biophysics in order to determine what makes it so peculiarly suitable for the purpose of telecommunication. To be valid, a discussion of this point, since it necessarily involves the notion of *damping*, demands that we should emphasize its theoretical character. All the writers who have dealt with propagation phenomena have been obliged in practice to apply correction factors to the laws. We must also look critically at the *objective* audiological reasons why whistles have the enormous range which, as clearly shown by observation in the field, they frequently have. We must also study the physical propagation of whistled languages in relation to the natural background noise which interferes with them. This must be done by considering the signal-to-noise ratio from the points of view of both the dynamic levels and the spectrum structure. This, of course, is valid only for the human decoder, who unlike a microphone is not passive, but is influenced by psychological factors such as attention and motivation, which are related to what we know of human auditory capabilities (classically defined by audiograms). These become important at the level of signal detection against noise and can produce quite astonishing performances.

Characteristics of Background Noise

In the natural surroundings in which whistles are normally propagated, the background noise is extremely variable. It depends on the geographical situation, the terrain, the vegetation, meteorological circumstances, the microclimate the signal has to traverse, and bio- and hydro-noises. All these parameters introduce a spread from optimal quiet to the noisiest situations. Optimal conditions occur chiefly during windless nights. Observed levels are of the order of 30 to 35 dB and the frequency range observed in the spectrum of Fig.19 shows that these levels are reached only for frequencies less than 150 Hz. If wind is blowing there is an additional noise and the total noise level may reach 50 dB. Analysis of the spectrum gives values of the order of 30 dB in the 1 kHz range and 20 dB at 4 kHz (Fig.19). In the mountain regions where all our whistled languages were observed, the most immediately noticeable characteristic of background noise was, up to 1970, the absence of "modern" noises (such as those produced by mechanically propelled vehicles), which constitute the background of our industrial civilization.

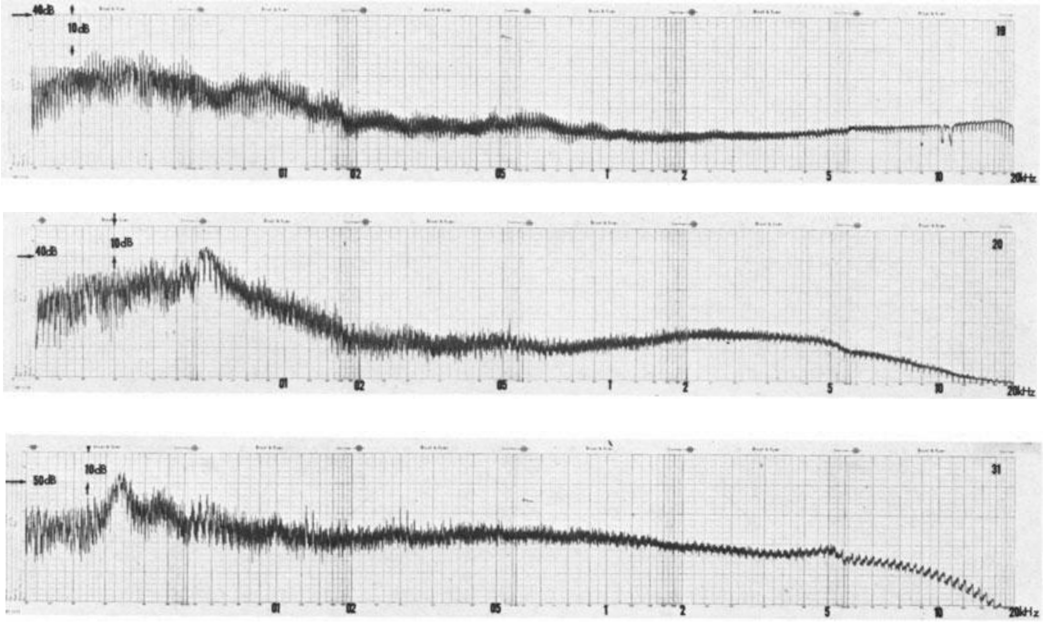

Fig.19 Spectrum of background noise, from top to bottom: Without wind, in winter, in the daytime, flat country; in summer, in the daytime, without wind, flat country; in a forest, in summer, with a wind speed of 5 m/s

Proper roads are to be found at La Gomera and at Aas; even so, on the island, they are few and far between, presumably a state of affairs likely to be continued for quite some time. This means that, apart from the sound of a few streams and wind in the trees--of which there is very little at La Gomera where most of the trees have been ruthlessly felled, except in the central highlands, and apart from strictly localized banana and palm plantations--background noise is enormously lower than in our technologically developed countries. It may be estimated at 20 to 30 dB during the day; hence the impression of profound quiet one has, except when a trade wind is blowing. Distant bird song is perfectly audible. At La Gomera, for example, a cockerel crowing (100 dB at 1 m) some four km away was heard clearly. Now, as we have shown, whistles can reach 110 to 120 dB in the frequency band 1-4 kHz. It follows that, in view of the level and spectrum of the natural background noise, there is a high probability of the whistled signal standing out, up to a quite respectable distance, according to certain laws which will be briefly stated in the next paragraph. On occasion, however, other types of interference have been known to occur. A curious kind was observed in 1956 on the upper slopes of the Alto de Gajaronay which are thickly covered with cedar trees and boast a large population of blackbirds. These reproduce accurately a number of human calls and were heard to whistle among other things "A María de los Ángeles, A Federico, A Rafael".

The question of whistling in the animal kingdom is examined in Chapter 7, but it may be pointed out here and now that such spontaneous imitation by wild birds of human acoustic signals poses an interesting problem. Parrots' and minah birds' mimicry is well known but, so far, had been observed only in the case of cage birds. In fact, it is known that certain species imitate the physical characteristics of certain signals, both of their mates and of other members of the species and even, in some cases, of other species. In particular widow-birds (Viduinae) are parasitic birds who mimic accurately the signals of their hosts [60]. Though the learning process is fairly well known as far as these birds are concerned, the case of wild Gomero blackbirds, confirmed by one experiment made in Great Britain (by A.C.), is as far as we know unique, even though we were aware of the fact that certain song birds are capable of being taught tunes whistled by the trainer (see also page 103).

Propagation

A formula concerning acoustic propagation in air states that *in theory* there is a decrease of intensity of 6 dB for each doubling of distance from the source and also that absorption is proportional to the square of the frequency, that it is relatively independent of humidity and depends only on temperature, which determines the velocity of propagation of sound in air. In practice atmospheric thermal gradients depend on wind and humidity, so that the influence of these factors is difficult to assess. These variations then influence range and by distorting the sound field create zones of acoustic shade. Temperature gradients can be equalized under certain conditions, especially in rainy weather, and transmission is then optimized. Similarly at night, when the wind has a tendency to drop, shadows are missing and the range is greatest. The importance of the wind is obvious, sound propagation being inversely proportional to the gradient of wind velocity. Hence the effects of temperature and wind velocity may be either added to or subtracted from each other. Knowledge of local meteorological conditions enables natives to form an excellent idea of optimal and minimal conditions of propagation. The degree of humidity has little effect except at very high frequencies when the atmosphere is very dry. At 1000 Hz, for 50% relative humidity, the intensity goes down by about 1 dB per 100 m. Fog has almost no influence on the low and medium frequencies used by whistlers.

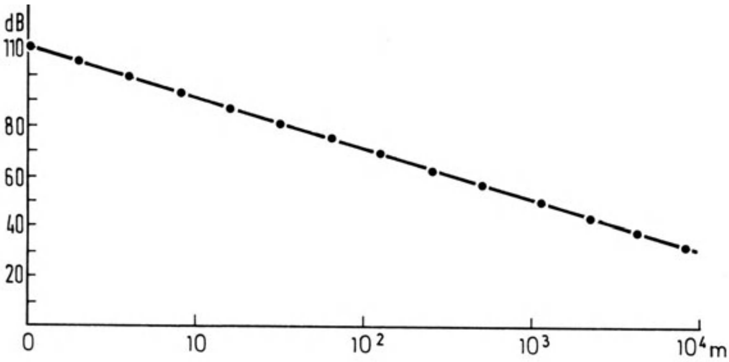

Fig.20 Theoretical sound propagation curve: abscissa in meters; ordinate in dB

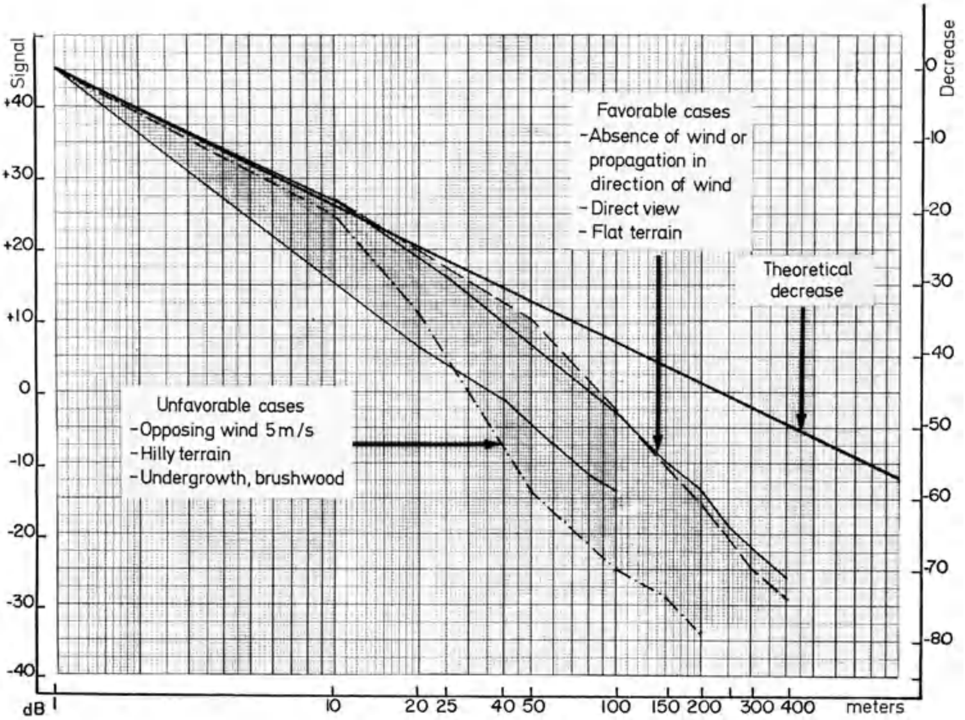

Fig.21 Experimental measurements of sound propagation in nature, in different circumstances, and curves of results expected according to theory. Unfavorable cases--contrary wind (wind velocity 5 m/s), abrupt terrain, trees and scrub. Favorable cases--no wind or propagation in wind direction, optical contact, flat country. Abscissa in meters; ordinate, signal attenuation in dB

A series of measurements obtained for sinusoidal signals over short distances produced damping curves from which it appears that values depend on: 1) wind direction and 2) existence or not of visual contact (presence/absence of vegetation, etc.). Figs.20 and 21 give a general idea of the diverse situations relatively to the theoretical curves. If we suppose that a whistle is emitted at 110 dB[13], the theoretical range is 34 dB at 10^4 m which means that at that distance it is superior or equal to the background noise. Admittedly the figure and the curve quoted are theoretical and our examples show that in practice a value of -6 dB for each doubling of distance is too low; twice this value would be more realistic. Nevertheless it is not surprising that in wooded, open valleys the range is generally limited to 2 to 3 km, whereas where the valleys are narrow, for example at La Gomera, with rock sides of low absorption, it is possible to reach 8 to 10 km. The curves referred to above relate to reception as a function of distance versus level on the one hand, and as a function of signal/noise ratio with reference to frequency on the other. It is clear that a whistled signal presents marked advantages over other acoustic signals and it is easy to understand how its physical characteristics enable it to emerge from the ambient noise.

If some of these considerations are characteristic of whistled languages exclusively because they are associated with the frequency band of this kind of signal, others are part of a larger problem, namely that of the learning faculty of the central nervous system. On this point we should like to report the following. We recorded a whistled signal at the source and, simultaneously, from a point 2000 m away but in visual contact, in flat country and on a windless day. Analysis by the sonagraph revealed an interesting fact: a significant portion of the frequency band had disappeared (Fig.22). Nevertheless the signal remains intelligible, for what remains of the informational skeleton amply suffices for a mental reconstruction of the message. Of course, the possibility of reconstruction is not the exclusive prerogative of whistled languages. Anything that has been learned--and language is a good example of form learning (pattern recognition)--can be analyzed as a whole by the brain through the consideration of the fragments of a pattern at various levels of the central nervous system which compares them with memorized matrices.

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[13] This surprisingly high figure is by no means exceptional. In fact, one of the writers (A.C.) can produce 117 dB at 1 m as measured with a B & K instrument. He heard a number of Silbadores who outperformed him by quite a few dB.

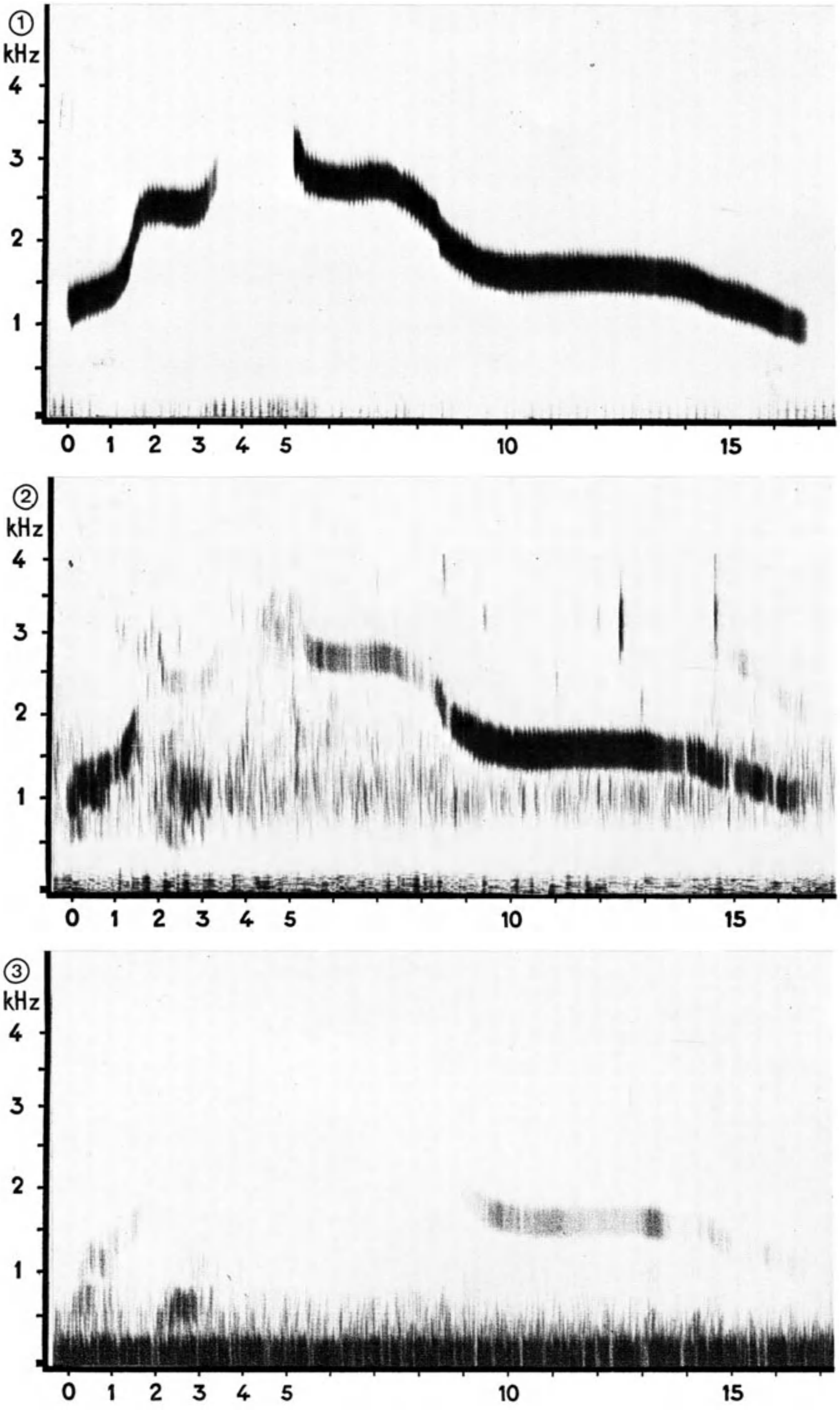


Fig.22 $S_1 - S_2 - S_3$ = Signal propagation: 1) signal recorded 1 meter from the whistler; 2) same signal recorded at 1 km, in plain; 3) at 2 km

At the level of auditory reception, man's external ear includes, as well as the auricle, a canal leading to the tympanum. This has not been extensively studied, as has the inner ear; yet it plays an important part in hearing. Measurements made with a microphone placed at the end of the canal, at the level of the ear drum, show that the frequency response is not linear; it exhibits a hump of the order of 20 to 25 dB in the range 1800-3000 Hz (Fig.23). The tube behaves like a closed pipe which resonates to and amplifies selectively a wave-length four times its own length. This is precisely in the range of maximum sensitivity of the ear, as measured on audiograms. Thus the ear is beautifully adapted to respond to whistles (on the level of biophysics) even better than to normal speech whose spectrum is complex. This makes it easy to accept the idea, and the fact, that whistles will always be better, i.e., more accurately, received, than the spoken word.

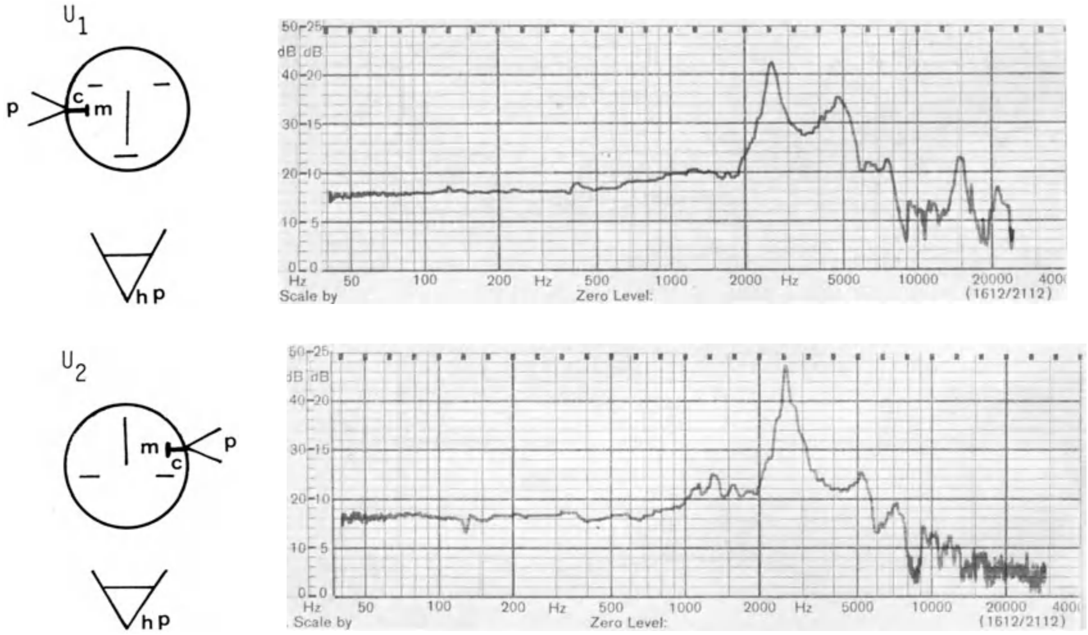


Fig.23 U_1 and U_2. Preferential frequency amplification in the ear canal (c), measured at ear drum. Microphone (m)-(U_1) with source (hP) facing; (U_2) with source behind the head-(P) auricle. B. and K. frequency analyzer

The receiver's motivation also plays an essential part in the process and, consequently, in the question of effective carrying power. An uninformed traveller who crosses tracts of land where a whistled language is in use pays no attention to it, so that the whistles he hears are only a component of the background noise. This partly explains the "secret" side of that form of language. In the small village of Assouste, a few furlongs from Aas, the locals are unaware of the existence of the Aas whistle. Whistles do not form part of our normal environment, our *umwelt*, and to be perceived in the true sense of the word, they must be, so to speak, unavoidable. It follows that the initiate, who is vigilant and motivated, will receive them even at low levels when the other will hear nothing. More, the ear and the brain, through the cocktail-party effect, can detect and analyze signals submerged under 3 to 6 dB of background noise so long as the receiver is motivated by semantic considerations or the personality of the sender. A good example of this is the conductor who, through the mass of instrumental sound, will detect one wrong note of which most listeners remain unaware.

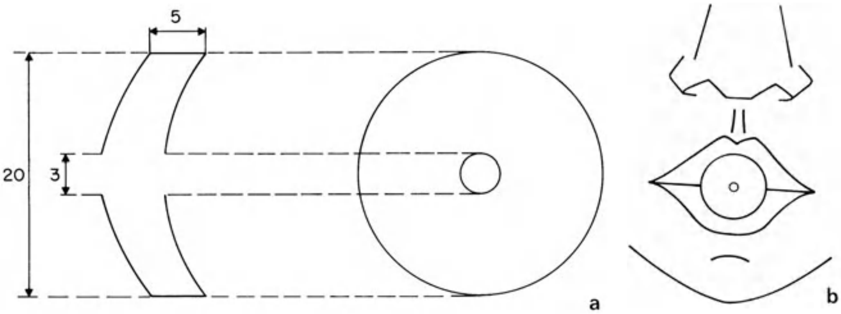
All this physical, biophysical, and psychological evidence tends to show that whistled signals possess all the required properties for optimum reception by the human ear. They have the necessary characteristics to make them stand out on the background noise within the limits of the weakening caused in practice by the environment, and the central nervous system of trained listeners, with its own characteristics, still further increases the ease of reception and decoding.

Chapter 4

The Mechanism of Whistle Production

As far as can be ascertained, the mechanism of whistle production by the human mouth, except in the case of the bilabial method, has failed to attract the attention of physicists. A brief discussion of the question may therefore not be amiss. Information on the bilabial type will be found in VON GIERKE's [35] article. It may be added that one kind of bird-call, which imitates the blackbird's song, seems to function much in the same way as the mouth in a labial whistle. Like it, it works equally well on expiration and inspiration, that is to say, it is immaterial whether the initiator precedes or follows the resonator/filter along the path of the air stream, the two arrangements producing acoustically indistinguishable results. All the other whistling techniques are different in this respect; they work only on expiration. A glance at the accompanying sketches will show the close similarity between the geometry of the bird call in use and that of the mouth emitting a bilabial whistle (Figs.24,25,26,27).

The whistles used by Gomero, French and Turkish practitioners are another story. When the question of whistled languages first came to our (A.C.) notice, we assumed--erroneously--that a human whistle was produced in a manner not essentially different from that of the artifact used by policemen and football referees, or indeed of musical instruments of the recorder type, all of which work on the principle of the *edge-tone* [9]. We arrived at this conclusion because these objects and the human mouth emit very similar noises whose wave-forms are scarcely to be distinguished from one another. In fact the modes of production differ. An edge-tone is produced when a stream of air, ideally issuing from a narrow slit, impinges upon, and is split by, a small-angle wedge placed in its path and parallel to it, so that eddies are formed on either side of the wedge. The wave-length of the motion, that is to say, the distance between successive vortices, is controlled by two factors: distance slit/wedge and air-stream velocity. If a resonator is coupled with this arrangement the wave-length will be determined by the resonator's own frequency, and if this can be made to vary in a controlled fashion



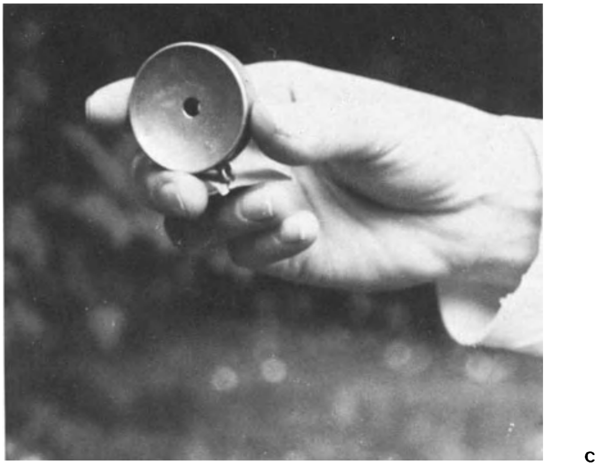


Fig.24a-c Bird-call: (a) dimensions in mm; (b) bird-call in use

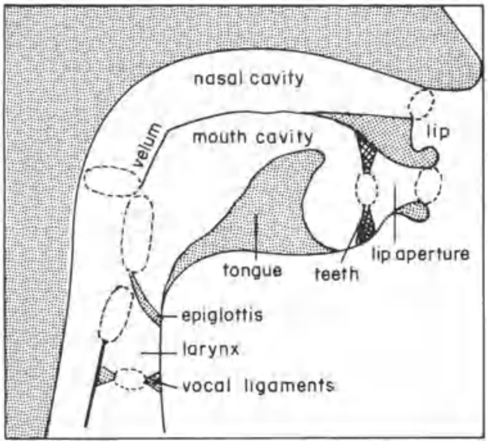


Fig.25 Sagittal section of mouth cavity

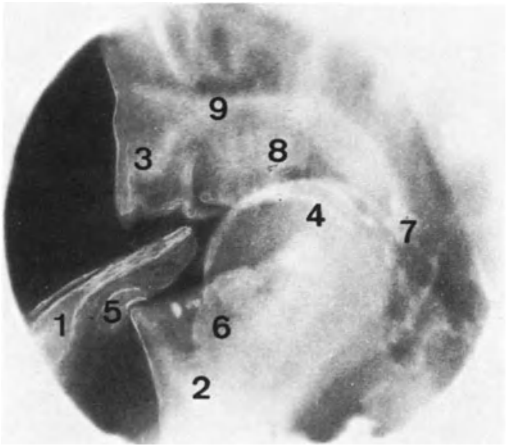


Fig.26 X-ray photograph from 16-mm film of whistler using method 2. 1-forefinger, 2-lower jaw, 3-teeth ridge, 4-tongue mass, 5-lower lip, 6-tip of tongue, 7-uvula, 8-mouth cavity, 9-roof of mouth

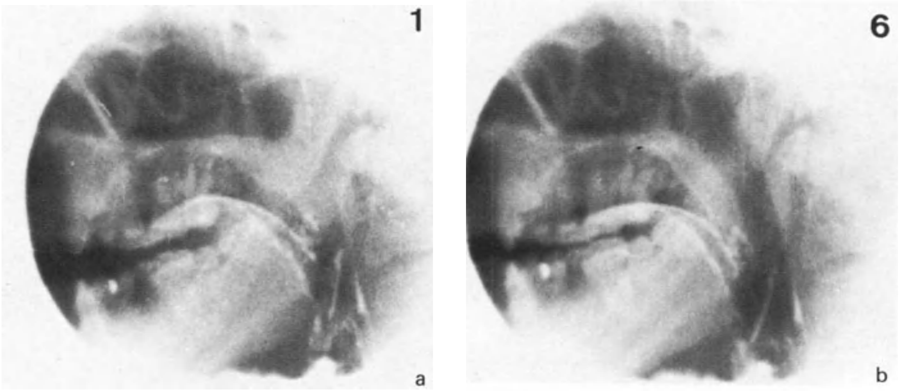


Fig.27a and b Two frames of X-ray film 5/24 s apart showing tongue displacement during articulation (method 1). Notice resulting variations of the volume of the mouth cavity

we have a musical instrument of the recorder or penny-whistle type. Now it can be seen that, owing to the anatomical structure of the teeth-lips system, the air-stream splitting arrangement cannot be duplicated by the human mouth since the upper incisors, although they can undoubtedly be regarded as an "edge" in the above sense, are set in a plane normal to the direction of the air current and cannot therefore split it. We must look for another explanation.

For want of an authoritative treatment the following hypothesis is tentatively offered. Whatever technique is favored (except lip-whistling)--tongue-teeth whistling, use of one finger or two in an assortment of positions--the whistler forms between the main cavity of the mouth and the outside a passage of more or less irregular and complicated shape which seems well designed to create considerable turbulence inside the mouth when air is expelled under pressure. The mouth cavity acts as a resonator of sufficiently high Q to be quite sharply tuned and not to absorb an undue amount of energy. The random motion of the air contained in the mouth is comparable to that of the air in a bottle when a note is extracted from it by blowing across its neck, the resonant frequency being determined by the geometry of the resonator in both cases. As far as the mouth is concerned, this can be altered at will within quite wide limits, movements of the whistler's tongue varying the volume of air in the speech tract. A little experimentation with the position of the tongue, lower jaw, and fingers shows that a number of combinations will secure the desired result with relatively little effort. The theory of this mechanism would be interesting but must be left to physicists to work out. The task is likely to prove somewhat difficult.

Given a normally sound set of teeth, anyone possesses all the equipment required for the production of a satisfactory whistle, although there exist a number of people, chiefly women, who seem to think that they do not. Of the many known whistling techniques none is more familiar than the bilabial one, in which the egressive air stream passes through a channel that begins at the level of the upper incisors and is continued through the lips which are strongly rounded and generally protruding. This is the way people achieve a more or less agreeable and musical result. The pitch variations which constitute the melody are effected solely by changes in the volume of air contained in the mouth cavity. These are made by raising and lowering the tongue mass as required, but cannot result from adjustments of the acoustic impedance of lip opening (the lips are fully occupied in the task of creating the necessary turbulence), nor by overblowing in the manner of the woodwind player. This bilabial whistle is never used at La Gomera, Aas, or Kusköy, at least for the purpose of telecommunication, undoubtedly because of the insufficient number of decibels it produces. At these places, it will be remembered, the whistled language is not used at close quarters. Another and probably more cogent reason is that its normal, comfortable frequency band is not very wide. On the other hand, it is a technique normally used in Mazateco country where short- and medium-distance whistled communication is the norm. Moreover, the frequency range, because it matches that of the tones of speech, is only of the order of one octave more or less. In the case of the Silbo Gomero all the methods about to be described are in common use. The list includes all the techniques observed at La Gomera, Aas, and Kusköy, but excludes the Mazateco leaf-whistle described on page 52.

1) Fingerless Method

The upper surface of the front of the tongue (the blade, in phonetic terminology) is grooved along its anteroposterior axis and is kept in contact with the edge of the upper incisors, forming a small aperture in the middle. The lips, generally rather spread, adhere firmly to the anterior surface of the teeth (Fig.1). Although a hand is often used to act as a kind of horn this appears to have no detectable influence on the acoustic result.

2) Two-finger Method

Two fingers, generally the forefinger, occasionally the middle or the little fingers of each hand, are brought into contact at the tip, forming a V, and are introduced into the mouth (Figs.2,3,4). At La Gomera they lie on the tongue blade which is thus immobilized. At Aas they may form a wider angle so that the tongue tip may keep enough freedom to be capable of a little movement, and X-ray films show that with some whistlers the tip does move. The same thing may obviously happen in the case of some of the other techniques described below. This can hardly be the result of a conscious effort on the part of the performer, as a little experimentation will demonstrate, but is almost certainly caused by the contractions of the main tongue mass behind the finger tips, for the seventeen lingual muscles enjoy relatively limited independence. The shape of the channel formed in the front of the mouth can be visualized readily enough. The air stream is obviously compelled to follow a tortuous path, and conditions favorable to the production of turbulence are created. Although it is possible, indeed quite easy, to whistle in this manner using two fingers of one hand, we have never seen this done for the purpose of communication at La Gomera, but it can be seen at Kusköy (Fig.2).

3) One-finger Method

a) The index finger is introduced into the mouth somewhat to the side and its first knuckle rests on the tongue blade. The lips are as usual kept tense and in contact with the front teeth. With the finger they form a small aperture, more often than not somewhat to the side of the mouth (Fig.28).

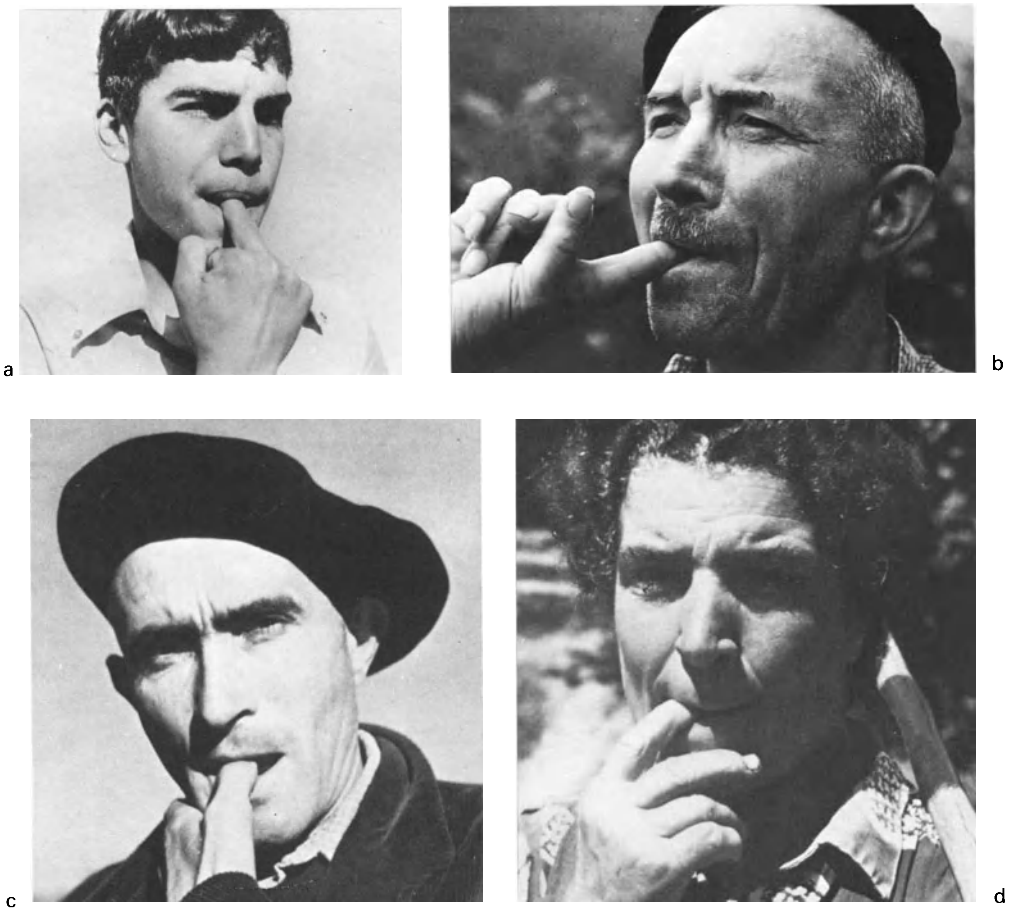


Fig.28a-d Whistlers, male and female, using method 3a. (The young boy is Gomero, the others are French)

b) The third knuckle of the bent first or second finger obstructs the major part of the lip opening, leaving a gap on one side; the outer side of the finger involved rests on the blade. The air path is clearly to one side of the mouth (Fig.29).

c) A similar technique is occasionally used with one finger--not bent--obstructing rather more than half the length of the mouth opening, leaving as before a short, narrow opening (Fig.29).

d) Finally we have a most important variant of 1) executed with one finger instead of two, this generally being the index, occasionally the auricular. This is bent so as to form a kind of E with the middle stroke missing

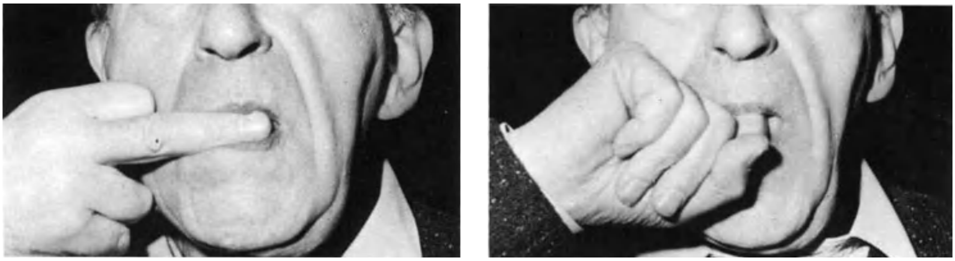


Fig.29 Gomero whistler: left, method 3c; right, 3b

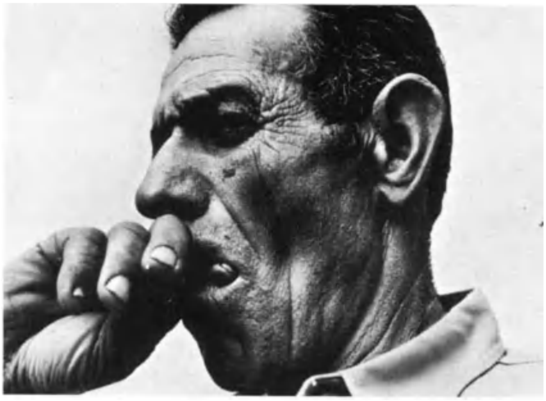


Fig.30a

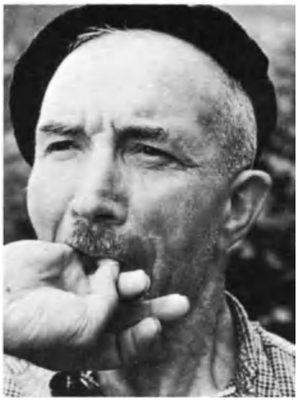


Fig.30b

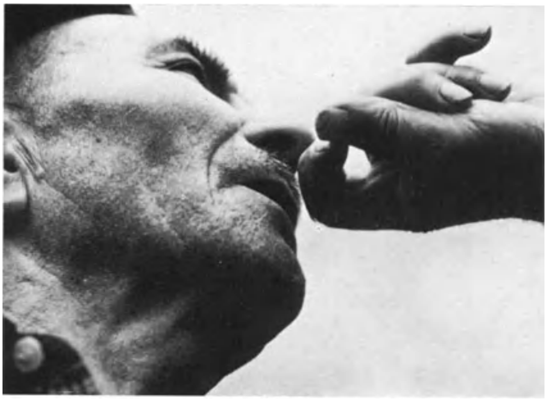


Fig.30c

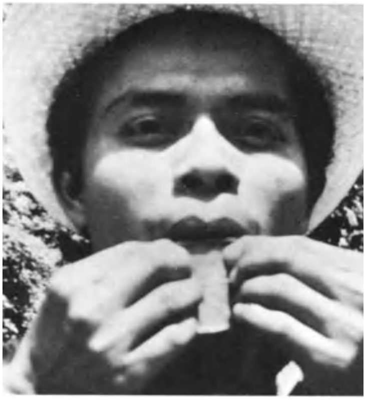
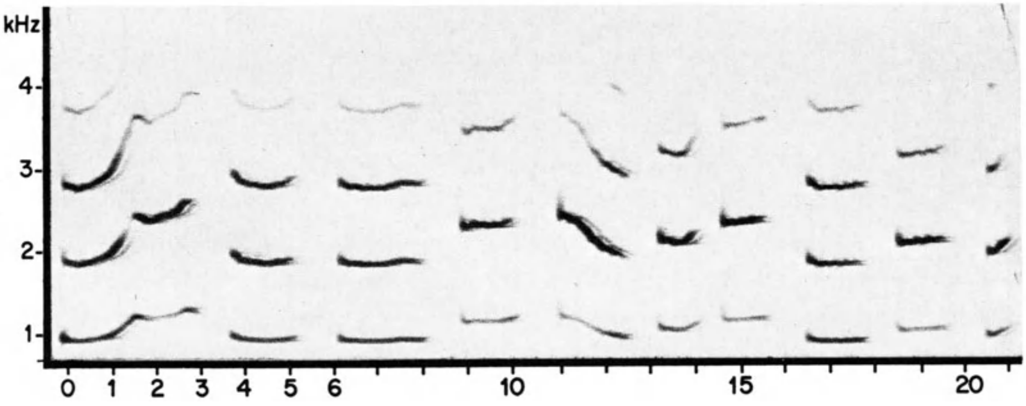
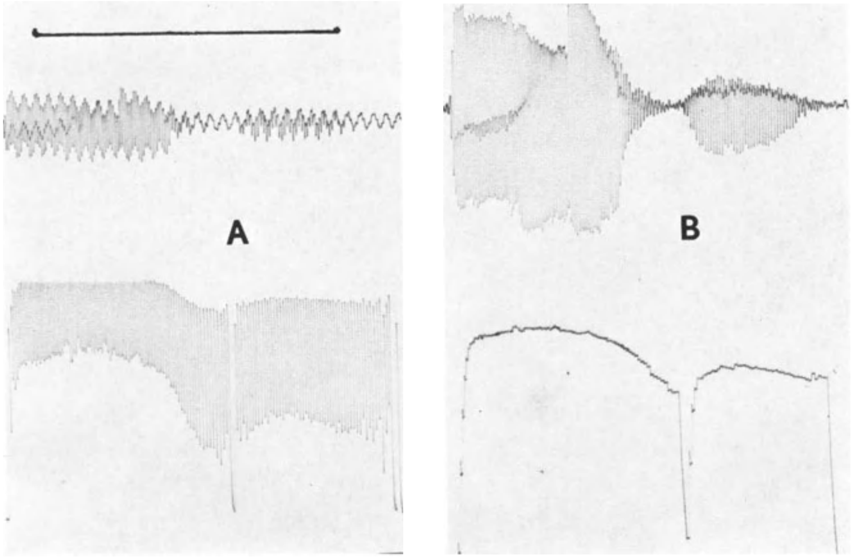


Fig.31

Fig.30a-c French and Gomero whistlers using method 3d
Fig.31 Mazateco boy using coffee leaf



a



b

Fig.32a Mazateco: Sound signal produced by whistler using coffee leaf. Sonagram - time 1/20 s. b Mazateco, tchao-ni-hi. (A) Curve of the fundamental frequency of the spoken form (pitch-meter) for comparison with that of the whistler's version (see Fig.17). (B) Same curve of spoken form obtained with Gautheron's "détecteur de mélodie" (Brevet ANVAR, Institut de Phonétique de Paris) - scale: 0.5 s

and is introduced quite deeply into the mouth. It rests upon the blade or even further back on the beginning of the front of the tongue (Fig.30). More often than not the hand not engaged in the actual process helps to keep the active finger in the right attitude and the right place, at the same time forming a horn, as described before. The air stream is forced over the middle knuckle which lies across its path, and emerges from the central opening of the lips contracted in the usual way. It can be seen that, once more, the air path is far from rectilinear. High air velocity is generally essential to initiate the required turbulence and this method is undoubtedly the best when very high levels of noise are desired. It is only when using this method that one of the authors can reach the level of 117 dB mentioned before.

The leaf method (Fig. 31) mentioned in Chapter 2 works on a different principle: the air stream impinging on the edge of a horizontally half leaf which is normal to it causes it to vibrate in the manner of a free reed. The resulting wave-form is a complex one quite unlike that of a whistle (Fig.32).

Chapter 5

Phonology and Phonetics of Whistled Speech

It was mentioned before that the techniques of whistling impose so many constraints and restrictions upon the articulation of speech sounds as they are usually performed in normal communication that a one-to-one correspondence between the sounds of speech and whistled signals could hardly be expected. In the case of the latter there occurs an important reduction in the number of significant features, and with them vanish many of the phonological oppositions that operate and we have come to expect in Spanish, French, etc. Particularly obvious and important are the losses resulting from the lack of regular voiced/voiceless oppositions of spoken consonants. These are clearly unavoidable in view of the fact that a voiceless whistle is a contradiction in terms, reducing as it does to a feeble fricative or better whispered noise useless for distant communication. Also the feature of nasality cannot play any role as such since the lowering of the velum involved in the nasalization of speech sounds has no effect on the timbre of a whistle which in all cases remains an overtoneless sound. It results only in a decrease of air pressure in the mouth with a concomitant reduction of loudness often amounting to total silence and no other observable acoustic effect.

As the limitations of whistling as compared with ordinary speech mechanisms must of necessity be identical whatever the language concerned, be it Spanish, French or Turkish, it is proposed to describe fully only one case of spoken-to-whistled language transfer because no new principle will be involved if it is desired to extend the study to another tongue that happens to possess an articulated whistled form.

On the assumption that Spanish is likely to be more familiar to the majority of readers than the Franco-Spanish Aas dialect or the Turkish one of Kusköy, we intend to limit our analysis to the Silbo Gomero, which in any case has been more fully investigated than the other two articulated whistles we are concerned with here. We shall in the first place give a very rough sketch of the phonology and phonetics of the Spanish spoken at La Gomera as they differ in a few particulars from those of Castilian, and also South American types. In general Canary Spanish is rather reminiscent of what one hears in the Câdiz region of the Peninsula, with a number of features one associates with certain Latin-American dialects as well.

The five vowel phonemes of the system, not including diphthongs, are shown below in the familiar Hellwag triangle, with some common realizations indicated in parentheses.

i (i į) u (u ų)
e (e ę) o (o ɔ)
a (a ɑ)

Because the exact quality of the vowel sounds has absolutely no relevance to our problem, no attempt is made to give a complete list or accurate description of variants. We merely indicate the existence of a few allophones that are heard in spoken Gomero. These, because their occurrence is governed exclusively by positional considerations, are of course freely interchangeable at the phonetic level and, even though the substitution of one for another might well sound odd or comical to the native ear, it would not noticeably impair intelligibility. This is a vitally important point when the message is whistled rather than spoken. Slight differences of timbre would appear in the form of pitch differences so slight as to be quite undetectable for most people. The significance of this point can best be demonstrated by considering what would happen in English, if it had its own Silbo, in the case of minimal pairs of the *beat/bit* type. In practice the only way the opposition could be made sufficiently obvious to the general ear would be to rely on the feature of length, to compensate for the inadequacy of the pitch opposition. Now this means in effect that a conventional element would be introduced, since the quantitative factor would not necessarily have the same value as in speech. In English the "short" *i* of *bit*, for example, can be at least as long as the "long" *ea* of *beat*. An arbitrary "code" procedure of this kind would hardly occur in the unselfconscious, unsophisticated linguistic practice of illiterates like the peasants of La Gomera. Although even primitive people can very well handle codes, introducing code features in what is a perfectly natural speech activity is altogether a different matter. These considerations naturally have the same validity in the Pyrenese and Turkey. As it is, we have in the present case five well-differentiated vowels, not too close to each other, from the point of view of either articulation or acoustic quality, i.e., resonance pitch. These correspond to five adequately differentiated pitches when whistled, so that they can easily be recognized by any normal ear, since it is merely a question of *comparing* relative pitches. In this respect the Gomero dialect lends itself singularly well to whistling, not having awkward features like the nasal vowels of Aas or the central vowel phonemes of Turkish.

In Spanish--and Gomero is orthodox in this respect--some of these vowels combine to form diphthongs: /ai ei oi au eu ou/. It is important to bear in mind that the diphthongs of Hispanic dialects differ markedly from the English type (*fate* [feit], *road* [rəʊd], etc.) which largely consist of glides, the articulating organ(s) moving smoothly and not particularly rapidly away from the point of departure to land somewhere in a more or less vaguely defined region. Spanish diphthongs, on the other hand, are formed by the juxtaposition of two vowels linked by a rapid movement of the articulating organ(s), and the duration of the transitional phase is minimal. The effect is not unlike that produced in French when two vowels form a hiatus in such a word as *pays*. It may also be said that the Spanish diphthong is in general character closer to the vowel of *side* [sʌid] than that of *sighed* [saed] in Scottish usage. The relevance of this will be apparent when we describe the whistled form of consonants, for these are realized for the most part in the shape of more or less complex glides, but are not ever confused with vowels or combinations of vowels, these being realized as steady or relatively steady pitches.

With trifling exceptions the Gomero vowel system closely resembles the Castilian at the phonemic level, and the phonetic differences, obvious as they are to the ear, are of minimal importance in a picture of the Silbo. Here the elimination of vowel *quality* necessarily obscures, if not eliminates, not only more or less subtle distinctions but even some which, in speech, are perfectly obvious to the most insensitive ear. But when such differences, however audible, are not functionally significant, they remain normally unnoticed by the native speaker who is primarily concerned with meaning rather than form. It is for example immaterial that the final [o] of *trigo* (wheat) should on occasions be realized as [u] ([trigu]) since any native speaker of Spanish hearing that form will not be tempted to identify it with [*trigi *trige *triga] (especially in the context) but uniquely with [trigo].

So far as consonants are concerned, the phonological and phonetic differences are undoubtedly more far reaching. Not only does Gomero lack, as do other non-Castilian dialects, two of the consonantal phonemes of cultured Spanish but, much more important from our point of view, some of the consonants are realized in an unusual manner, their allophones[14] becoming in certain circumstances virtually interchangeable. It will be shown that the phonetic as well as the phonemic peculiarities of Canary Spanish (in effect all simplifications and a decrease in the total number of possible oppositions) make for an easier and more efficient adaptation to a whistled form of the language than a fuller and more complex system such as Castilian would permit.

As is frequently the case with a good many other dialects the system includes neither a palatalized /l/ which is replaced by *yod* (*se cayo* = *se callo*) nor the interdental fricative of *cero* (*cazar* = *casar*). (As regards the former it is in any case virtually on its last legs almost everywhere). Now it is well known that a small number of phonemes does not necessarily entail a correspondingly small number of different sounds since there is no theoretical limit to the number of possible allophones. Nevertheless in general fewer phonemes tends to mean fewer sounds, and in this instance the phonetic system, lacking as it does certain phonemes, is also the poorer by a corresponding number of units. That this should be possible--as indeed it is also in many other forms of Spanish, both peninsular and Latin-American--without creating a serious decrease in the efficiency of the system seems to indicate a high degree of redundancy in the language.

The chief consonant sounds of Gomero appear in Table 2. The list is not meant to be exhaustive since all the features not directly related to the whistled version of the language have been excluded as a matter of policy.

Table 2 Consonantal phonemes of Gomero

p b		td		kg
			č	
m		n	ñ	
	f	s		x
		l		
		r r̄		
w			j	(w)

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[14] Readers unfamiliar with linguistic terminology might like to be reminded that allophones are phonetically diverse realizations of the same phoneme, the choice of one or the other being determined by the phonetic environment.

Many of the sounds are naturally enough used exactly as in Castilian. For example /b d g/ appear as plosives or fricatives according to the phonetic context precisely under the same conditions as in Spain; /t d/, normally dental, become alveolar after *n* which is itself alveolar, /n/ is realized as a velar before *k g*, etc. Nevertheless, in order to make what follows more readily intelligible to the non-Hispanist reader, we shall discuss (very briefly) the phonetic in relation to the phonemic system of Gomero. [z] does not appear in the table, not because normal assimilations are unknown in Canary Spanish, but because preconsonantal *s* is reduced to a slight, often almost inaudible, aspiration--*Justin*, Castilian [xustin], Gomero [xu^{h}tin] [hut^{h}in] and even, with some speakers very nearly [^{h}utin], so weak is the [^{h}].

[p] The normal nonaspirated voiceless bilabial plosive of Spanish. It is the normal realization of *p* and there is no allophone.[15]

[b] A fully voiced bilabial plosive which is a realization of /b/ when this occurs at the absolute initial or after /m/. It is worth noting that its articulation involves little muscular tension as compared with say the French version of this phoneme.

[^{t}] Most often a voiceless nonaspirated dental plosive articulated much in the same way as the tip, not blade, variety of French /t/. It realizes *t* in all positions except that it does not occur after an alveolar consonant (*l n*), in which position it is replaced by [t].

[t] As [^{t}] except that the articulation is alveolar, that is to say, the tip of the tongue instead of touching the upper incisors comes into contact with the teeth ridge. It is the result of an assimilating process.[16]

[^{d}] To all intents and purposes can be described as a voiced form of [t] as described above, but occurs only at the absolute initial and, in modified form, after /l n/ when it becomes

[d] which is in effect a voiced form of [t] as described above.

[k] This is the normal voiceless, nonaspirated velar plosive whose point of articulation shifts back and forth according to the nature of the following vowel. It is the most common realization of /k/.

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[15] When phrases like "there is no allophone" occur in the text of this chapter it should be taken to mean no more than "as far as analyzing and understanding the mechanism of the Silbo goes, we can safely proceed as if there were no variant of any consequence".

[16] The distinction between the two types of /t/ vanishes in the Silbo, where /t/ is realized as a front, not blade or tip, consonant.

[g] For practical purposes can be called a voiced [k]. It realizes /g/ initially and after a nasal.

[tʃ] This is the normal voiceless affricate of Spanish, acoustically resembling the *ch* of English *chap* but articulated in a slightly different way. The occlusive initial element involves the blade of the tongue so that the cavity resonance is higher pitched than it is in English. There is no voiced form nor any allophone. It invariably realizes /č/, spelled *ch* in ordinary orthography.

[m] This is the common bilabial nasal, usually articulated with little energy. There is no allophone, at any rate in the Silbo. Realizes /m/.

[n] In Spanish this nasal is alveolar although [t d] are dental. It usually corresponds to the spelling *n* and realizes /n/ but not invariably. For example final /m/ is realized as [n]: album Abraham (surname, the Christian name is Abrahan) [alβun aβran]. It seems capable of functioning as an allophone of /r/ in final position *comer* [komer, komen].

[ñ] This palatalized *n* acoustically resembles the group [nj] but is not interchangeable with it. A pronunciation [arseño] for [arsenjo] will not be acceptable. Normally it is pronounced with extensive contact of the upper surface of the tongue with the hard palate. Very little muscular tension is involved; the tongue just touches and does not exert any pressure. There is no allophone.

[ŋ] This velar nasal does not exist as an independent phoneme in Spanish. It is merely an allophone of /n/ which occurs after a velar plosive. It is very much the same sound as in English and it occurs under the same conditions.

[β] A voiced bilabial fricative which is in fact an incompletely articulated [b] in which the lips fail to come into actual contact so that at no point is the speech tract occluded. It is an allophone of /b/ which occurs in all positions except at the absolute initial and after /m/ where /b/ is realized as [b], as described above.

[f] An ordinary labio-dental, indistinguishable in practice from English or French [f]. It has a very low frequency in Spanish, especially initially.

[ð] This is to /d/ as [β] is to /b/ and can be described as an incompletely articulated [d], the tip of the tongue failing to reach the upper incisors so that a narrowing of the speech tract instead of occlusion takes place. The result is a fricative or perhaps more often a frictionless continuant acoustically quite distinct from the English (inter)dental fricative of *this*, *then*. It realizes /d/ in all positions except at the absolute initial and after /n/ and /l/. In Gomero it frequently represents an allophone of /r/, at least finally--*Pilar* [pilað].

[s] This sound is more often than not palatalized to a certain extent, but generally not nearly so much as for example in popular Madrid dialect. It is invariably a realization of /s/ and no other phoneme, but it occurs only in front of a vowel. In any other position /s/ appears in another form as described below.

[x] This voiceless velar fricative is pronounced with considerably less vigor than in Castilian, being frequently reduced to a kind of not very strong aspirate ([h]). Even then the articulation remains primarily velar but the speech tract shows so little constriction that acoustically it is scarcely to be distinguished from a pure glottal fricative. It can be a realization of final /k/ in words like *block*.

[ɣ] This is an allophone of /g/ and it stands in the same relation to [g] as [β] does to [b] and [ð] to [d]. It occurs in all positions for /g/ except at the absolute initial and after [ŋ].

[h] There is no /h/ phoneme in Spanish but the sound, or rather a very weak form of it, occurs regularly in Gomero, as well as in a number of other dialects (for example, Andalusian) as a realization of /s/ in all positions except before a vowel. It is so weakly articulated in most cases that it can be practically inaudible, in which case /s/ may be said to have almost a zero realization; however, the listener is still often conscious of a difference between two words, one with, the other without, *s*, e.g., *Justin* v. *Jutin* because there appears to be a minimal gap in the flow of sound where in Castilian the [s] would occur.

[l] This is a perfectly ordinary "clear" *l* (one with a high front resonance) which tends to be very short in final position.

[r] This consonant is a realization of two distinct phonemes /r/ (rolled) and ɾ (semi-rolled). The existence of numerous minimal pairs (corro-coro, karro-karo, torrero-torero, etc.) makes it clear that there exist two /r/ phonemes, but the latent opposition is often neutralized under conditions that are well known but do not need to be recalled here. This is because in the Silbo, owing to the impossibility of articulating normally any variety of front *r*, the only one known in normal Spanish, the rr-r opposition inevitably vanishes.

It may be added that in whistled Gomero the /rr-r/ phonemes are rather shabbily treated.

[ɾ] This corresponds uniquely to /r/. It is a perfectly ordinary semi-rolled (also called "flapped") consonant; it is very weakly articulated in the final position. In Gomero it often appears as an allophone of several quite different Spanish phonemes--*sud* [sul, sur, suð]; *sequidillas* [seɣiðijaʰ], [seɣiɾijaʰ], *silbo* [silβo, siɾβo], *comer* [komer, komen]. Something similar can often be observed in Andalusia and elsewhere.

[w] This is an ordinary [w] very similar to the English semi-vowel, but in Spanish it is always fully voiced except after a voiceless consonant, which causes partial unvoicing through assimilation. It is among other things a realization of /g w/, *agua* [awa], *guagua* [wawa], etc.

[j] This semi-vowel too is very much like the corresponding English one, but it often becomes much more consonantal in the initial position where it can become considerably affricated--*ya* [dʒa].

We are now in a position to examine the fundamental problem of the Silbo, and incidentally of other articulated whistled forms of language: what happens when the spoken word is converted into a whistled signal. It has already been made clear that the opposition voiceless/voiced as such is obliterated in the case of consonants (the question naturally does not arise with vowels); some other feature must replace it in the emission, in order that identification may be possible. But we shall first look at vowels which present the advantage of being easily accounted for; moreover, a knowledge of their simple mechanism makes that of the more complicated consonants readily intelligible.

In what now follows, it is assumed that one finger of each hand is inserted in the mouth (method 2, Fig.2,4), not because anything is significantly altered when other methods are favored by the whistler, but because it is easier to imagine the various constraints imposed upon the articulation when the front part of the tongue is maintained in a fixed position by mechanical means, i.e., vertical pressure of the fingers upon the tongue-blade.

Vowels

The action of the lips is the more obviously noticeable factor and, in a negative sort of way, a most important one. Whereas in speech they are active and assume many different attitudes for all the vowels of the system--

being more or less spread to form a slit for the front series ([i e], etc.), more or less rounded for the back ([u o])--in the Silbo they are kept absolutely rigid and immovable. This means that the tuning of the pharyngo-buccal resonator is unaffected by variations of the aperture area which determines the impedance of the passage. As far as front vowels are concerned this is of little consequence and the situation is not very different from what obtains in ordinary speech. As long as spreading is not actually converted into rounding with consequent excessive change in the impedance of the aperture, the acoustic effect is relatively slight because the pitch of cavity resonance is not greatly altered. The tongue position, which changes the volume of the cavity, has more effect. On the contrary, in the case of the back series of vowels, the area of the front aperture has a much greater role to play as can easily be verified experimentally. In the vowels of the English words *boot* and *hot* a marked rise of pitch is heard in the passage from one to the other. If now the same two vowels are *whistled*--a lip-whistle is perfectly satisfactory for the purpose of this test--the relative pitches of resonance of the two vowels are reversed and the note of *o* is very much lower than that of *u*. The reason for this interesting phenomenon is obvious enough. In whistling we keep the acoustic impedance of the lip opening constant, for the purpose of sound production, whereas in speech we normally have a quite small aperture for the *oo* and a quite large one for the *o*; this results in a lowering of pitch for the first vowel. Now it is a well-known fact that if we whisper the series [i e a o u] we hear steadily descending pitches. If the whisper phonation is replaced by any kind of whistle, the same thing happens, except that the last vowel of the series is displaced and appears to have an abnormally high pitch. The reason is not that it is raised but rather that the neighboring vowels have been lowered by being articulated with abnormal lip rounding. Of course, with whistle-phonation, timbre differences are automatically eliminated since a whistle is an approximation to a sine wave, and the quality of a sound is related to the pitch and intensity of higher components in a complex wave. In the whistle, differences of timbre appear as differences of pitch. This functions quite efficiently, from the point of view of communication, because the differences of pitch levels are very obvious. If the intervals are large enough, relatively poor ears can cope with them. There is a particularly sizeable one between [e] and [a] so that in the Silbo, front and back vowels distribute themselves very neatly into a distinct pair of series. This contributes greatly to the easy identification of whistled vowels. It is worth noticing that the difference between certain pairs such as /a o/, although large and easily maintained, is often in practice allowed to become blurred, given a suitable context, because the Silbador does not make distinctions which he considers superfluous. For instance, when calling Antonia Padilla Sanchez, if there is no Antonio Padilla Sanchez in the vicinity and confusion is therefore practically impossible, the final vowel of the first name will more often than not be whistled in such a way that it could be interpreted as either an *a* or an *o*, but it will unmistakably be a back vowel, i.e., one that could not possibly be *i* or *e*. In any case, a certain looseness of articulation in the case of back vowels is by no means uncommon in current conversation. We have already mentioned [trigu] for [trigo]. Certain assimilations are of the same kind. "Hablo a Morales que si me presta..." appears in one of our recordings as [aβla:morale^{h}...] where the regular sinalefa [oa] is replaced by a lengthened [a:] somewhere between [a] and [ɒ].

When diphthongs are whistled, the sudden change of pitch level involved in the passage from the first vowel to the next is so abrupt that the combination could not possibly be confused with a consonant glide, which we shall deal with in the next section. Diphthongs are in general perfectly explicit, but one point needs mentioning. No method exists in the Silbo that will permit a distinction to be made between two diphthongs identical except as regards their increasing or decreasing character--aú v. áu (*baúl caucho*). This would seem to be unimportant in view of the fact that no minimal pair involving the two types has been found in the lexis of Gomero whistlers. This is fortunate since there would be no *natural* way round this particular ambiguity (although conventional solutions are not hard to devise) because, generally speaking, stress does not appear ever to be indicated in the Silbo. Spanish prominence is largely dynamic, and whistling, because it is used for telecommunication, always aims at maximum loudness. One interesting exception will be described when we come to deal with *esdrújulo* (proparoxitone) forms, under *prosodic features*. It may be said that this negative treatment of dynamic stress has never been found to lead to ambiguity or confusion, that is to say, loss of efficiency.

Consonants

These set some problems which, as could reasonably be expected in view of the variety and relative complexity of their articulation, are a good deal thornier than anything connected with vowels. Two main parameters suffice to characterize Spanish vocalic phonemes: zone of articulation (front or back) and degrees of closure since labialization is inoperative in whistling. Speaking in terms of the Silbo this means in effect that we have to deal only with five approximately fixed volumes of the mouth cavity and these correspond acoustically to five more or less stable pitch ranges. Consonants on the other hand consist largely of transient phenomena, in most cases devoid of any significant static phase. Even in relatively simple systems the contrasting features tend to be fairly numerous, since oppositions are based on a multiplicity of parameters: place of articulation, of which there are a good many; modes of articulation, also numerous; phonation types. All of these are susceptible to combination in an assortment of ways and therefore are capable of producing widely different auditory effects which will appear in the form of a more or less complex system of pitch variations when they are whistled rather than spoken.

Even a cursory inspection of the sonagrams reveals that there is a very close correspondence between the sound systems of Gomero, Aas and Kusköy whistles. In what follows all the consonants are described in their complete form, that is to say as they appear in the intervocalic position. Initially some cannot be identified with certainty and this may well be one of the reasons why whistlers, when calling someone, invariably preface the name with a signal interpreted at La Gomera as "Ah". At Aas and Kusköy, where such a beginning is also the rule, its function is, according to the whistlers, to attracts the attention of potential listeners. At these places it is said to correspond to "O". It is in fact meaningless but plays an important role in making any following consonant intervocalic instead of initial so that it is heard complete. The importance of this fact will be appreciated if it is borne in mind that in the act of ordinary verbal communication a vast amount of guessing is the norm. Only a fraction--sometimes a small one--of the signal is actually heard in informal English conversation, but the native hearer's linguistic conditioning as well as the redundancy of the system permits an integral reconstruction of the message. Most people have experienced the discomfort of listening to an imperfectly known foreign language. Many things that would be immediately grasped if read, when the signals are perceived integrally, become totally unintelligible because lack of familiarity with the medium excludes the possibility of performing the large amount of guesswork done unconsciously and effortlessly by the native. Now the situation is very different in the case of whistled communication where in general everything is heard but, because phonemic/phonetic redundancy is minimal as compared with that of speech, many significant features are missing. Clearly any avoidable sacrifice is highly undesirable; on the contrary, the advisability of keeping the initial consonants complete whenever possible scarcely needs stressing. It is not suggested that such considerations are, or ever were, present in the minds of whistled-language users, but there is little doubt that experience must have led them to conclusions similar to the ones we have arrived at.

It is proposed in the first place to examine the treatment of plosives, but not, as is customary in conventional phonetics, as voiceless/voiced pairs, but as two independent series, lumping together, instead, the three voiceless phonemes /p t k/ on the one hand, and the corresponding voiced ones, /b d g/, on the other. It will be seen immediately that this procedure is forced upon us by the fact that the first three phonemes are invariably realized as stops, whereas the other three turn out to be, in a very large majority of cases, continuants, even more frequently than is the case in spoken Spanish. Owing to the prevalent practice of prefixing [a] to initial groups, consonants appear at the initial less frequently than in speech so that the occurrence frequency of voiced stops is low, except after nasals and, in the case of /d/ /l/ as well. It follows that for /p t k b d g/ the voiceless/voiced opposition is largely neutralized in whistled Spanish, even in the cases where it is the rule in speech. It is somewhat startling that in practice no ambiguity should result from this.

Now, the articulation of [t] and [k] during the production of a whistle results in a stoppage of the air stream and consequently of the carrier frequency, since a part of the tongue, remaining free to move, obstructs the speech tract during the middle phase of the articulation. But, as the lips are immobilized with all the techniques in use, they cannot block the air passage, and some other method must be resorted to in order that the characteristic gap characteristic of the emission of plosives should occur. Two methods are available. The flow of air can be interrupted by the action of the thorax muscle and of the diaphragm, and this is the way Silbadores do it. Alternatively lip closure can be replaced by a glottal occlusion, which seems acceptable to Gomeros at least although we (A.C.) have never observed them doing it,[17] presumably because the glottal stop is, to the best of our knowledge, altogether unknown in the phonetic system of all Spanish dialects, and certainly to that of Canarian. In any case, the acoustic difference between the results of the two techniques, although just perceptible at close quarters, is beyond detection at a distance of even only a few yards. /p/ then is realized as a brief silent interval, contiguous sounds remaining substantially unaffected, whereas /t/ and /k/ possess certain identifying features because the tongue, moving to and from its position of articulation, influences the resonance pitch of the vowels with which they are in contact, more especially in the neighborhood of their boundaries. This duplicates precisely the events of normal speech where, as is well known, the articulation of occlusives, where they are in contact with surrounding vowels, modifies the pitch of their formants and thus permits their identification.

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[17] On this point we have no information concerning what happens at Aas and Kusköy.

Admittedly juncture phenomena in ordinary and whistled speech must exhibit marked differences since in the latter, but not in the former to a like extent, the carrier frequency is very nearly continuous, except when interrupted by an actual occlusion of the speech tract or a lowering of the velum which decreases the air supply to the mouth and diminishes the volume of sound emitted to the point of extinction. Nevertheless, in view of the fact that the spoken vowels of Spanish are essentially steady and without tendency to diphthongization, it is not unreasonable to posit that, in their whistled form, their limits coincide with the limits of level pitches. If this is admitted, a dental like [t] consists of a steep up-glide corresponding to the implosive phase of the articulation, followed by a silent gap produced by the occlusion, and finally another rapid glide, downwards this time, towards the level of the following vowel or other segment, this being the plosive phase. The length of the glides, that is to say the frequency range covered, is determined by the resonance frequency of the surrounding sounds. For example, in a combination like [oto] it goes from a note near the bottom of the whistler's range to his "top note". In [iti], on the other hand, the glides, although still very clearly audible, are obviously much narrower, the surrounding vowels being themselves near the upper limit of the range. If the two vowels belong respectively to the high and low ranges, as in [ito], the glides will be characterized accordingly; see Fig.33(3-6). A similar process comes into play in the case of [k]. It might be thought a priori that this consonant would in practice be difficult to distinguish from [t] since the modes of articulation are identical and the whistle contains no formant. But, although the *mode* of articulation is the same for both, the

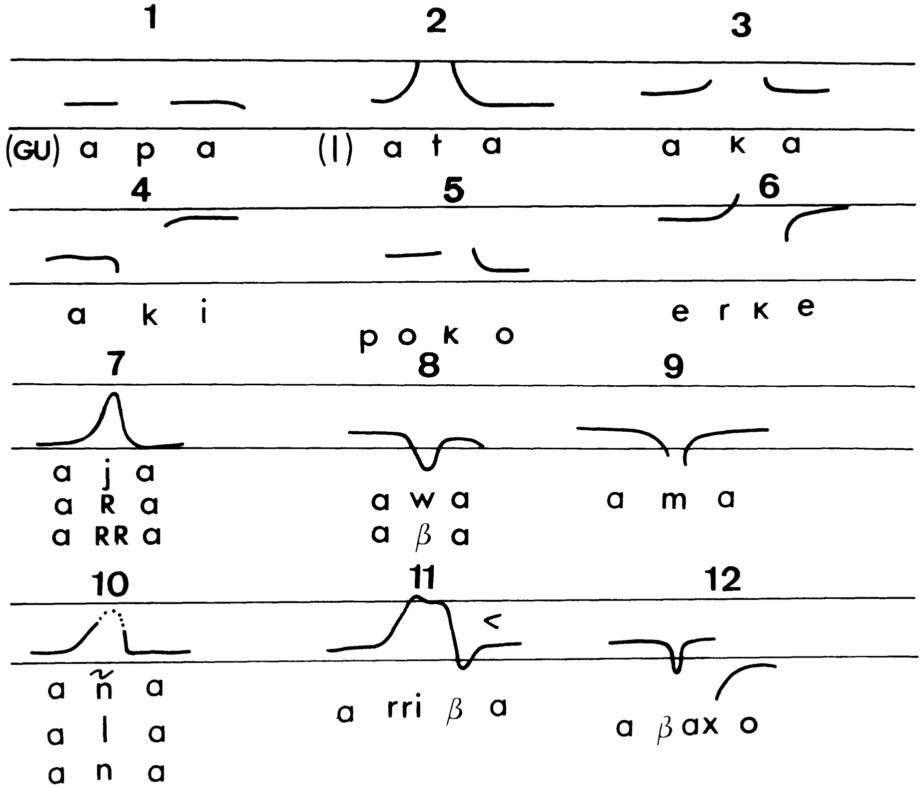

Fig.33 Gomero: These curves represent the listener's auditory interpretation of whistled signal for a number of consonants. It is interesting to compare them with the curves obtained instrumentally (sonagrams). The horizontal lines represent an interval of about one octave

place is not and the acoustic results are completely different. A moment's reflection will show that the profile of the roof of the mouth must ensure that raising the front of the tongue to bring it into contact with the hard palate, a movement which covers a considerable distance when starting from a neutral position of rest, is not at all the same as bringing the back of the tongue into contact with the velum, this movement being necessarily a narrower one since the distance from the back of the tongue to the velum, with the organs of speech at rest, is not very considerable. The k-glides are, *ceteris paribus*, narrower than the t-glides (see Fig.33).

An immediately striking fact will not have escaped the reader's notice: these curves, drawn freehand, which represent what is heard, bear a marked resemblance to the second formant of the sonagrams obtained for the corresponding spoken segments as they appear in, for example, Potter, Kopp, and

Green's *Visible Speech.*[18] The coincidence of the graphs for speech and whistle is evidently the result of the general similarity of the articulations. [k] is a particularly interesting case. The curves of contiguous vowels have an up or down inflection, depending on whether their second formant is lower or higher than the "hub" (in P.K.G.'s terminology) of [k]. These considerations explain why voiceless plosives, although they consist largely of gaps in the flow of sound, can be identified by listeners.

The affricate of *mucho* [tʃ], unlike that of English *much*, has a blade articulation. From the auditory point of view it places itself somewhere between an affricate and a strongly aspirated plosive with, obviously, an element of palatalization. In articulatory terms, one of the main differences with Spanish [t] is the speed of movement; the release of [tʃ], as compared with that of [t], takes place in slow motion. This results, in whistled language, in a less steep down-glide, the implosion having the same shape in both cases. It may be mentioned that the acoustic difference, difficult to perceive in the early stages of learning the Silbo, becomes clear after some experience has been gained. This, of course, is a common phenomenon in language learning: the non-native is not in a position to discriminate between redundant and significant features. Unfortunately pitch analyzers and sonagraphs are precisely in the situation of untutored foreigners in this respect and may well put the emphasis on the irrelevant while neglecting the important.

[β ð ɣ] As in speech these realize /b d g/ except initially and after nasal and, in the case of /d/, after [l]. No other consonant involves closure of the speech tract at any point. As will appear presently, this does not signify that the carrier whistle goes on almost uninterruptedly. A decrease in the velocity of the ejected air stream can produce an effect similar to that of an occlusion by reducing the acoustic power to such an extent that even at a relatively short distance the effect is that of a gap in the sound [ð] and [ɣ]. [ð] and [ɣ] are, from the whistler's point of view, merely the ordinary consonants except that the point of articulation of [d], is shifted in a posterior direction. It is worth mentioning that at La Gomera and, for that matter, often in other places, these three consonants turn out not to be fricatives in the strict sense of the word and, in view of the laxness of their articulation, they could be more accurately described as frictionless continuants, and often weak ones at that. In the case of [ð] in particular it frequently happens that no friction whatsoever is audible, the sound being articulated merely as a tuning of the mouth cavity, and the total disappearance of the consonant in the intervocalic position is a common occurrence: [toðo] > [too].

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[18] New York, D. van Nostrand Co. 1947.

[β] The whistler, when producing this consonant, can be observed endeavoring to substitute for the lip narrowing of the spoken articulation some equivalent means of acting on the vibrating air stream. No native performer--not unexpectedly--could give a subjective description of the process, and we are reduced to describing the method we use personally to achieve the desired result. As it is difficult to imagine an alternative procedure there is a high probability that Silbadores do in fact use the same one. When the whistler comes to the consonant in question he tries to reproduce the sensations experienced in a normal articulation and also, naturally, to obtain an acoustic effect comparable to that produced in speech. He reduces, by the action of the diaphragm and the thorax muscles, the expelled air pressure, and this is automatically accompanied by a general relaxation of the muscles of articulation, so that the tongue naturally moves towards a neutral position of rest. Immediately, the normal working pressure is resumed at the same time as the tongue starts moving to the next position of articulation. The acoustic result, which is easy to imagine, is shown in Fig.33. It is, after some practice, very easy to associate with the spoken version of the sound.

[ð] appears as a continuous up- and down-glide not unlike an intervocalic [t] but without the silent phase, since the rising tongue reverses its movement before contact with the hard palate is made. Since the volume of the mouth resonator does not shrink to the same extent as for [t] the pitch does not quite reach the same extreme height. In final position the down phase of the glide is missing and the consonant ends on an extremely high pitch. As shown in Fig.33, /d/, when realized as a plosive because of the phonetic context, is indistinguishable from [t].

[γ] During the articulation the back of the tongue rises and reaches a position close to the soft palate. Even though there is no actual contact with it, which means that it is definitely a continuant and not a stop, the speech tract is so constricted in the region of articulation that a marked lowering of breath pressure occurs in front of the point of articulation at the moment of maximum narrowing and the intensity of the sound may decrease almost to the vanishing point, in fact to such a degree that one may easily think that a stop consonant is being articulated. This, in fact, is the conclusion which the present writer (A.C.) mistakenly reached in the first place. This erroneous impression was corrected only when experience and practice showed that it is by no means essential to close the speech tract completely at some point to interrupt a whistle. The consonant then is realized as a downward inflection of moderate amplitude, with or without an audible gap in the middle, depending on the degree of energy the whistler puts into the articulation. If this tends to be rather lax, and it often does, the rise of the tongue will be limited, the pitch will be only moderately lowered and the whistle tone will suffer no interruption. The acoustic result will then be very similar to that produced by [w] and [ʙ]. This was of course to be expected, for phonetic reasons so obvious that they need not be labored here.

We can now go into the questions of nasal consonants. These, in normal speech, are so striking that even linguistically naive listeners are vaguely aware of the fact that there is something rather special about them. In the same way, if perhaps a little less obviously, people whose native tongue does not possess nasal vowels tend to think of these as almost belonging to an entirely different category of speech sounds. On the contrary, as JONES[19] pointed out a long time ago, there is nothing very remarkable about a nasal, or nasalized, whistle. Indeed, how could there be? From the physiological point of view nasalizations result from a downward movement of the velum which puts the nasal resonator in parallel with the mouth cavity. Acoustically, this means that, in ordinary speech, the formants are considerably lowered. The lowering is so marked in some cases that it can be demonstrated without any kind of measuring instrument. For example it is impossible to sing without distorting it the vowel ã of French *champ* on a note higher than F sharp in the octave above the middle octave of the piano, as pointed out a long time ago by PAGET[20], because the first formant of this vowel is lower than that note. In the case of a whistle, the effect of opening the nasal tract results merely in diverting the air stream, or a large part of it, from the turbulence-producing system of the mouth orifice and the whistle just peters out. If the velum is only slightly lowered so that the resistance to the egress of air is so considerable that very little escapes that way, the whistle will continue, perhaps with the loss of a few dB. But no one a couple of yards away will be able to guess the cause of the pitch variation which could just as easily and just as well be caused by tongue as by velum movements. The influence on the formants, hence on the timbre, will be nil.

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[19] D. Jones: Pronunciation of English (Heiffer, Cambridge 1912).

[20] R. Paget: Human Speech (Harcourt, Brace, New York 1930).

There are no formants since, as we know, all the parameters of ordinary speech are replaced in whistled speech by a meagre brace of them (or one, if one prefers--it is only a question of terminology), frequency and time. Yet nasal consonants can be identified with ease in the Silbo, only not as such. As will be shown presently this phonetic category is deeply involved in the extensive system of neutralizations always to be found in whistled languages because of the inevitable reduction in the number of phonetic categories. This means that the above remarks are equally valid for consonants and vowels. Since it is not proposed to duplicate or triplicate the analysis by dealing with Aas and Kusköy whistled speech as we are dealing with the Silbo, we can point out en passant that the Aas dialect has one nasal vowel (õ) which, when whistled, is not recognizable as such. It appears in the normal vowel series at a place determined by the total volume of the resonators involved in the articulation. From the point of view of the efficiency of the system, this is clearly unimportant. So long as a sound can be distinguished from the others, it does not matter by what means this is achieved.

Passing now from the general to the particular, we shall now look at the three nasal phonemes of Spanish, /m n ñ/, and their whistled realizations.

[m] This, being a bilabial articulation, may be said to have no existence as such, as far as whistling is concerned. However, it is easily identified in its whistled form. The lowering of the soft palate, by putting the nasal cavity in communication with the mouth cavity, greatly increases the total volume of resonating air. Now, whether because of the resultant decrease of available air pressure, or because the turbulent system at the lips does not contain components of sufficiently low frequency capable of exciting a cavity exceeding certain dimensions, the following phenomenon can be observed. An abrupt fall of pitch ending in a brief silent interval occurs and is followed immediately by a rapid rise to the level of the next vowel, this clearly resulting from the combined movements of the tongue from neutral to the vowel position, and the simultaneous raising of the velum to the closed position. It will be realized that the two movements add up. The acoustic effect can be seen in Fig.33.

As far as the velum is concerned the above description is valid for the next consonant [n]. But this time other factors intervene, specifically the raising of the tongue in the direction of, and as far as, the hard palate, with which it should in principle come into contact as it does in speech.

Now it is a curious fact that in the majority of cases, this position of closure of the speech tract is not actually reached and the whistle in consequence is continuous, consisting in a rapid up-and-down inflection of the frequency curve, the mirror image of an [m] executed without a silent gap at its nadir. This can only be taken to mean that, quite unconsciously of course, the whistler feels that above all, [n] is a voiced consonant and he chooses between two aspects of the sound: the articulatory, which would demand contact between the tongue-palate, hence an interruption in the whistle, and the auditory, when the voiced aspect of the sound requires continuity in the phonation, as in speech. It is interesting that different whistlers elect different solutions. The two versions occur with approximately equal frequencies, but it seems that whistlers who aim at maximum power, because of topographical or weather conditions, or just because they have a reputation to think of prefer the fully articulated lingual stop. Fig. shows the two forms. As in the case of other consonants, [n] in the final position shows only the initial rise and sheds the falling phase of the complete articulation.

[ɲ] is indistinguishable from [n]. This could have been expected since [ɲ] is a palatalized [n], and, when whistled, [n] is necessarily palatalized. This feature of palatalization in a whistle is purely articulatory and has no auditory reality. /n/ and /ñ/ are then realized identically and, when whistled, cannot be the terms of an opposition. This does not appear to give rise to frequent ambiguities, because the number of minimal pairs involving the contrast /n-ñ/ in Spanish is by no means large. Three Silbadores were observed regularly to make a distinction between the two phonemes. The palatalized form would be whistled as a continuant; the [n] would have the gap described above. The distinction may not have been artificial, because other whistlers were heard to make it, although not consistently, but no explanation of this practice has occurred to the present writers.

[f] This, being a labio-dental fricative, cannot possibly be articulated at all when whistling, unless a bilabial technique is used, in which case some kind of frictional noise can be produced. In Gomero, Aas and Kusköy dialect, its presence is deduced from its effect on the following sound since its production is exclusively an affair of breath. A syllable such as [fe], for instance, will consist in a long glide from the bottom of the range up to the level of the following vowel. At close quarters, the emission of breath corresponding to the [f] is clearly perceptible, but it is the form

of the vowel which, instead of being relatively level includes a sharply rising portion, makes recognition of the whole segment possible.

[s], as far as distribution is concerned, is treated in the same way as it is in speech where, as we pointed out before, it is a dental fricative (slightly palatalized as a rule) only before a vowel and a weak aspirate elsewhere. In terms of the Silbo this means that it is totally inaudible except prevocalically, when its production, which consists in raising the front part of the tongue towards the hard palate and simultaneously interrupting the emission of the whistle, results in a sound not unlike whistled [t], except that the up-and-down glide has generally a narrower range. This indicates that whereas the "unvoicing" of [t] is in fact the result of an occlusive articulation, it is not necessarily the case for [s] which seems to be produced with the passage opened throughout the articulation, so that its "unvoicing" is presumably the result of a conscious act on the part of the whistler.

[x], in the Canaries, whether spoken or whistled, amounts to a kind of [h], not necessarily a very energetic one. It is hardly ever more strongly articulated than the corresponding (very gentle) Russian sound. In view of this, one might well except a not very forcible kind of articulation when it occurs in the Silbo. Judging by the acoustic result, possibly because of an unconscious desire to achieve maximum clarity when using a system only too given to obliterate many significant oppositions, the whistler makes a serious effort to whistle an easily identifiable [x]. Something of this kind was seen to take place in the case of [f] which, because of its action on neighboring sounds, it more audible when whistled than when spoken. For [x] it looks as if the back of the tongue takes a very active part in the game and more than makes up for the enforced inactivity of the lips. Reference to Fig.33 shows that the consonant begins with a break in the carrier which is followed immediately by a rapid rising glide to the level of the next vowel. The ear, which, in such matters at least, gives more information than the eye, tells us that [x] which looks very much like an [f] on an oscillogram, differs from it in that the slope of the glide is much steeper than for [f], suggesting greater force of articulation and breath pressure. This makes one think that the articulation of the whistled jota is similar to that of the spoken Castilian jota. That this should be possible is because the movements of the part of the tongue concerned in this articulation are totally unimpeded, whatever the whistling technique in use. As seen in Fig.33, [l]

and [r] can conveniently be dealt with together. Since, except in the case of a labial whistle, it is manifestly impossible to articulate any kind of front [r] or a normal lateral that will be audible beyond a couple of meters, the whistled form of both these sounds reduces them to an up-and-down glide, the result of an up-and-down movement performed by the part of the tongue that lies immediately behind the blade, which, in one way or another, is immobilized. This is exactly comparable with the production of other front consonants. The auditory result, shown in Fig.33, is, as could have been expected, identical with one of the forms of [n] and [ð]. To this may be added [j] which, being necessarily articulated in the same place and in the same way by the same part of the tongue, has precisely the same whistled form.

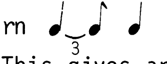
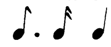
[w]. This semi-vowel is often described as a more or less consonantal form to [u], and this admittedly corresponds well enough with one aspect of reality. In whistled speech, sonagrams exhibit it as a dip in the frequency curve, whatever the surrounding vowels. Between two [o] the vowel [u] would occupy a higher level. This is explained by the fact that in the whistled production of [w] the back of the tongue rises to the greatest possible height, stopping just short of actual contact with the velum, with the dual results that the air supply is much reduced, and the acoustic impedance of the back passage very much increased. The curve for [w], as Fig.33 shows, resembles closely that for [β].

Consonant Clusters

The description of these need not detain us long for several reasons. In the first place, they are relatively rare in Spanish; in the second, they never include more than three components, two in the Silbo, at the lexical level; and in the third place, even pairs of consonants, when one of these is /s/, reduce to one (*esta*, spoken form [e^{h}ta], whistled form [eta], similarly *pastel* spoken [pa^{h}tel] whistled [patel]). Triplets, if they include both *s* and *r*, also reduce to one unit when whistled (*canastra* is whistled as [kanata]) because /r/ following a dental behaves in a rather peculiar fashion as will appear presently. Other combinations present no problem and the components appear with their normal form. As for /r/ in contact with a preceding [t], because the place and manner of articulation of the two sounds are so similar, a sort of fusion of the two takes place, and [tr] + vowel is not to be distinguished from [t] + vowel. It would be quite possible to articulate them in succession, but the need to do so is evidently not felt by practitioners. This habit presents a further advantage, apart from its simplicity; it obviates the possibility of confusion with [pr] and [kr] for examples which present for their part no difficulty. In these the /r/ remains quite recognizable.

Figure 33 may give the reader more useful information and a clearer idea of the nature of the signals than will an examination of the corresponding sonagrams because it shows what the whistler/listener extracts from the signal rather than the acoustic signal itself. In other words, a kind of phonological analysis has been performed on it. It often happens that a distinctive feature, in whistled as in ordinary speech, has little physical prominence while a redundant one sticks out like a sore thumb on a graph, because for a microphone there is no such thing as redundancy and a contrasting feature is neither more nor less important than anything else that impinges on its diaphragm. The hand-drawn curves of Fig.33, being in effect a phonetic dictation to someone possessing an adequate knowledge of the medium, shows the features that carry the semantic information, neither more nor less, hence the differences between them and the curves obtained instrumentally. That these differences should turn out to be perhaps less extensive than might have been expected in view of the above considerations may well be due to the fact that a modulated whistle, as a physical phenomenon, is extremely simple and cannot in the nature of things carry a vast amount of redundancy. In any case, the user of a communication system based on acoustic signals, spoken, whistled or played on some kind of instrument, once past the learning stage, reacts to overall patterns rather than to the sum of a large number of discrete features.

The Prosodic Aspect

Although, as pointed out before, there is no dynamic accent as such in the Silbo, and this in spite of the fact that accent in Spanish manifests itself as a stress, it is possible to give prominence to certain syllables, whenever necessary, by other means. In the first place, the fact that vowels do not have a fixed pitch but rather occupy a frequency band of a certain width clearly makes it possible to differentiate between otherwise identical vowels by allotting to them different places within the band. For instance, a sentence such as "Ven por abajo" contains one word (abajo) in which the first two vowels could be expected to be whistled at the same level. In practice, because the second one carries the stress, it is *always* whistled on a higher note than the first: $\overline{a\beta}\ \bar{\ddot{a}}\ \overline{xo}$. Less obviously, we often observe that a vowel, when it carries the word-stress, occupies the upper region of the frequency band whereas it would be at the lower end when unstressed, even apart from syntactical considerations such as operate in the previous example. Another process seems to be used in proparoxytone words (esdrūjulo) in which what could be called the normal accentual pattern is disturbed. For instance, the word *cā́ntaro* is stressed on the first syllable, which carries a graphic accent, although in general words ending in a vowel are a paroxytone. In such cases, the natural rhythm of the spoken word, specifically the distribution of quantity, assumes in the whistled version a markedly exaggerated form, long syllables becoming longer and short ones shorter. Thus, spoken *cā́ntaro* produces the pattern  (more or less) but is converted into  by the whistler. This gives an unmistakable indication of the place of stress in such words. These prosodic markers, rudimentary though they may be, are amply adequate for practical purposes. One should not forget that Spanish is not a language that relies heavily on accentual contrasts of the type (English) 'increase/in'crease, 'insult/in'sult, and it is no exaggeration to assert that prominence features have extremely little importance in an articulated whistle.

Nor can intonation be said to play a vital role in the system--indeed it is immediately obvious that it could not possibly do so without inferfering with it more than could be tolerated since extensive use of prosodic frequency variations would swamp the phonological pitch oppositions. One might as well, in the whistled version of a tone language, expect to have the timbre of vowels accurately represented at the same time as its tone. In an enormous majority of cases, irreconcilable clashes would inevitably occur. Admittedly a system of conventions could evolve that would get over these difficulties but users of whistled languages who are avid readers of CHOMSKY[21] are not thick on the ground. Of course the situation is not quite so difficult in the case of an articulated whistle, as could be inferred from what was said in the section about stress features. It should be borne in mind that Spanish intonation (and stress) is not the syntactical and affective instrument it is in English. Functionally Spanish intonation is much nearer French and it is much more useful in expressing emotional nuances than grammatical facts.

In the Silbo its role is practically limited to opposing questions to statements, as will be described presently, and very little else. Even then it is not relied upon exclusively, either by whistlers or by speakers. Instead of saying "¿Me has visto la cabra que me falta?" the shepherd makes use of interrogative words which will turn the sentence into a question, whatever the intonation: "¿Que si me has visto la cabra que me falta?" The "Que si" not merely reinforces, it could actually replace the rising intonation that in speech would normally be given to the question. But in fact, it does not. The intonation of questions *does* differ from that of statements, whistled or spoken. The system is undoubtedly rather crude and can be described in simple terms. Statements, commands and all expressions of an affirmative or negative nature may be said not to have an intonation, in the sense that pitch variations are determined exclusively by the resonance of the mouth cavity which is itself merely a matter of articulation. This is true of the body of the whole utterance, but the final stressed vowel is generally somewhat protracted--in the case of some whistlers enormously so--and, if it is a low-pitched one, occupies the bottom of the normal band. Low-pitched vowels tend to have a slowish downward glide. In a question the same long vowel would show a slow rise:

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[21] N. Chomsky: Syntactic Structures (Mouton, The Hague 1957).

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-
a β a x̅o̅
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High vowels, on the other hand, however prolonged, tend to remain level:

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 -                      -
        -                       - -
Ven p̄or aquī            Ven pōr acá
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Questions, whether or not they begin with an interrogative word, receive a rising intonation. The final vowel begins at the normal pitch, is prolonged, and rises slowly, the process being much less abrupt than in the case of diphthongs and consonant glides. Not infrequently the pitch level of the whole vowel is brought up to that of the next vowel in the series. This happens more often with low-pitched back vowels than with front ones because they are too near the top of the range to allow much latitude, especially [i] and [e]. Raising the tongue from the [i] position, for example, would result in an occlusion. All in all, prosodic features tend to have limited significance in the articulated whistled languages we have examined.

The question of syllabification can be disposed of very briefly. In most cases juncture is not marked in any very obvious way. Not that whistlers are not normally aware of the existence of the syllable as a phonetic unit, but by nature the signal does not lend itself to the manufacture of clear-cut syllables. In any case, from the point of view of intelligibility, there is no great need for it, as even a superficial look at the structure of the syllable in Spanish demonstrates. The fundamental types, which are few in number, are in order of frequency CV, VC, V, VC + C(C)V. Now, in articulated whistled speech, vowels and consonants are immediately identifiable by their acoustic form since vowels are characterized by a substantially level pitch, consonants mainly by glides which may or may not include a gap in the whistle, or rarely by just a gap, as in the articulation of [p]. In other words, the juncture phenomena are reduced to variations of the frequency of the carrier tone in precisely the same way as segmental features are. Herein lies one of the basic differences between the phonetics of the spoken and of the whistled word.

Dialects

From the linguistic point of view the whistled form of the Gomero dialects presents only very few interesting features. They are calques of the spoken versions and what differences are observable are chiefly a question of mean frequency range. This is primarily a matter of habit and depends in no way on linguistic factors. It may be said that in general the use of the highest range is customary around about San Sebastián. In the north there is a marked tendency to make use of a noticeably lower range, and this is also true of the central region, from the Alto de Gajaronay northwards. On the west side of the island there seems to exist a preference for a form pitched about half-way between the first two, but perhaps a little nearer the eastern form. Some of the whistlers heard in the north and more particularly in the west, in the region of Valley Gran Rey, Chipude, Santa Catalina, used a lower pitched signal than the others. They were on the whole somewhat older than other performers but their practice did not appear to be linked with different linguistic habits and their speech was indistinguishable from that of other whistlers.

Their technique was undoubtedly responsible for the frequency range they favored: they produce the signal by means of methods 3a and 3d (Chap.4). The fingerless method hardly ever produced anything but a high- or medium-pitched whistle, and a change in the whistling technique could produce a transposition up or down. For example, Esteban Herrera, from Molinito, who normally used method 2, if asked to demonstrate method 3d, transposed his Silbo down. Technique 3 is particularly associated with low pitches because the introduction of a large bent finger, often the size of a small banana, between the teeth automatically forces a lowering of the bottom jaw. It follows that the fundamental frequency of the mouth resonator with the tongue in the neutral position of rest is often about an octave lower than when most other methods are employed. It is this factor that accounts for the variations of mean range from whistler to whistler even though the tongue movements are basically identical. For example, with the front of the tongue raised to the position of articulation of /i/ (in *aquí*) the pitch will be higher when there is no finger to keep the lower maxillary down than it if is permanently kept in an "open" position by any means whatsoever, since in the latter case the volume of air in the mouth behind the zone of articulation will be greater than in the former. It will be remembered that absolute pitches are irrelevant. Only the position of a vowel on the scale used by the whistler is of any consequence, and consonants are identified almost entirely by their contours.

What has been said of the Silbo fits with minor modifications both the Aas and the Kusköy whistled languages. For instance, in the case of the former, the addition of one nasal vowel, which in any case loses its nasality when whistled; in the case of the latter, of one central vowel which naturally falls into place in the vowel series when whistled, would suffice to specify the vowel system completely. Nor is there any new factor to be considered when we come to consonants which are treated identically in the three languages insofar as they coincide. One might be tempted to conclude from these considerations that all articulated whistled languages are so fundamentally identical that mastery of one of them would automatically guarantee mastery of all the others, assuming a knowledge of the base language, of course.

As it happens it seems that such a conclusion would not be justified. COWAN, in a paper entitled "Whistled Tepehua" [26,27] refers to a type said to be markedly unlike the three we have investigated. The differences may be briefly characterized as follows. From Cowan's account, the consonants of Tepehua are produced with enormously greater accuracy than those of Gomera, Aas and Kusköy, to the extent that nasal consonants are recognizable as such when whistled. Moreover, many prosodic features are stated to be preserved, since whistled Tepehua apparently makes great use of stress and "the sentence intonation contours of spoken Tepehua are reproduced in the whistle". It may be said at once that anyone with a first-hand knowledge of the three whistled languages described in this monograph but none of Tepehua will be thoroughly baffled on all three counts, for reasons which will be immediately obvious. In whistled Spanish, French, and Turkish there seems to be total incompatibility, except in the most rudimentary way, between the expression of speech intonation or, for that matter, tone, and the precise conversion of tone quality into a pitch characteristic. One or the other must necessarily be to a very large extent sacrificed. The same may be said of the realization of stress as described in the same article: "Stressed syllables have a high rising glide, especially if the stress is on the penultimate syllable, or a high falling glide, if stress occurs on the last syllable". We are unmistakably given reason to assume that in the case of accented syllables the articulation and acoustic quality of the vowel itself have no relevance, and Cowan's next sentence reinforces this impression: "The interaction and mutual condition of sentence intonation and word stress is assumed but still not analysed". It follows from this that stress in speech must have the intonations said to go with it in the whistle. Alternatively, one must infer that the sentence tune has gone by the board, at the same time as the contrastive function of the timbre (expressed as pitch) of stressed vowels.

Since Tepehuan, as we are told, is not a tone language, one might be tempted to think of its whistled version as one does of a shorthand system of the Pitman type, which dispenses with vowel indications altogether, but with precise indications of consonants, and also rather accurate realization of certain prosodic features, although on the whole intonation seems to have the worst of it. Unfortunately, at first sight at least, all this seems difficult to reconcile with another statement made in the same paper: "Both [i.e., Tepehua and the Silbo (A.C.)] give a differenciation of vowels based on a combination of relative pitch and transitional glides...". The puzzle is to reconcile this with the first sentence quoted above concerning stressed syllables where the shape of the glides is unambiguously stated to be determined by the presence of a stress and the place of the vowel in the word, not by the fact that it is open or close, front or back. If "...of the five vowels /i/, /a/ and /u/, for example, /i/ is *usually* [our italics (A.C.)] highest in pitch, /u/ lower and /a/ lowest", one must suppose that "usually" means "in all positions except under stress, when prosodic considerations become paramount and swamp everything else". This difficulty may well be only an apparent one and it is hoped that an explanation will be forthcoming. It is conceivable, for example, that as suggested above, the whole vowel scheme of Tepehua rests on a systematic compromise, vowel quality being normally expressed by the resonance pitch of the mouth cavity but that there is special treatment of tonic syllables when the expression of stress becomes all important. But no ready explanation occurs to one which will reconcile this with the expression of intonation as well.

The question of consonant expression is even more baffling in the absence of a physical/physiological description of consonantal phonemes. On the assumption that we have to deal exclusively with a whistled phonation, Cowan's account contains a number of statements difficult to interpret. He writes, among other things, that "All consonants are actually pronounced, with considerably audibility of fricatives". Now, it all depends on what you mean by "pronounced". If it is to be interpreted as *articulated*, well and good. In an articulated whistle you naturally articulate consonants, or try to, just as you do vowels, within the limits imposed by the physical constraints. It is true of Gomero, Aas and Ksköy, as it must surely be true of Tepehua. If on the other hand it is suggested that with a whistled phonation it is feasible to produce anything but variations of the fundamental frequency, this cannot be accepted.

What could a fricative whistle be, and how could it be recognized except by the process of mentally translating pitch contours into the physiological movements that created them and which, in their turn, are unconsciously identified with these or similar movements as they occur in ordinary speech? In a whistled signal you can observe three features, neither more nor less--pitch, duration, loudness. Clearly, extraneous noises such as laryngeal buzzes, groans, friction, clicks, etc., which are inaudible a few yards away, are negligible in practice. In other words, all you can infer from the frequency modulation of the signal--the only audible feature--is how the volume of the mouth resonators varies in the course of the performance. Suppose you articulate [apa], disregarding stress and intonation, by emitting a whistled tone and performing tongue movements corresponding approximately to a normal articulation of the segments. You obtain at the receiving end an auditory impression roughly shown by the graph of Fig.33. Repeat the experiment with [aøa], voluntarily interrupting the carrier for the duration of the consonant, or part of it; ten yards away [aøa] will be almost indistinguishable from [apa]. At a slightly greater distance the two groups will sound rigorously identical. Now Cowan emphasizes that fricatives are recognizable as such; if he means that their contours are different from those of, say, most plosives, this is of course perfectly acceptable. If he means that the various modes of articulation are recognizable in the same way as they are in speech, that is to say because they are noises of a different quality, this can only mean that something beyond a whistled phonation is involved in their production. We are unfortunately not told whether all consonantal phonemes are equally identifiable whatever the distance over which communication takes place, as they are in whistled Gomero, Aas, and Kusköy. From the information available, one might be tempted to think that we are dealing here with a mixed technique of sound production since a whistle is in the nature of things incapable of making use of the majority of speech parameters, but is limited to the three we have enumerated. It is not easy to imagine how the distinction said to be made in Tepehua between aspirated and unaspirated plosives comes about, since the only effect of aspiration, as experiment seems to show, is to prolong the silent phase of the stop by a small increment, not easily detectable unless artificially, i.e., conventionally, magnified. The same can be said of the "fricative release of affricates" [27]. Similarly, the description of front or central vowels + velar stop (e.g., [ik]) as involving a "long slurring glide in the whistle and a visible pulling of the lip and face muscles as the tongue changes position" suggests a dissimilarity between speech and whistle articulation which might well indicate the presence of some conventional, that is to say, code, features.

Again, that the bilabial nasal should be voiceless, "sometimes without complete closure of the lips" is hardly unexpected, since the dying out of the sound would naturally occur when the velum is lowered, as in the case of other nasals. What *is* unexpected is that a nasal consonant should be identified as such in the absence of a context. As Daniel Jones pointed out some considerable time ago, "...these is nothing very remarkable about a nasalized whistle", by which he meant that, assuming that it is heard at all, a nasalized whistle will sound exactly the same as a non-nasal whistle of the same pitch. But no doubt Cowan will solve all these puzzles in some future publication.

The Case of Tone Languages

These must inevitably receive a very different treatment. In fact, the problem of transferring tone languages to a whistled form has a much simpler solution than could reasonably have been expected; but a little reflection shows that it is the most obvious and certainly the simplest one. If the pitch contour of successive syllables is no less significant than the combinations of those bundles of audio-articulatory features which for users of no-tone languages constitute the information-carrying elements of language, the whistler is faced with an inescapable dilemma. He can dispense with tone contrasts to preserve segmental features by utilizing the frequency variations thus made available to convert timbre opposition into frequency modulation. This process preserves the acoustic contrasts, although it is of course done in an abnormal way by a process of substitution. Speakers of tone languages seem, when they whistle, invariably to keep the supra-segmental features rather than articulatory ones. The tongue movements which, in any type of whistling, control the volume, i.e., the tuning, of the mouth, are then completely divorced from the physio-phonetic concept of articulation. That whistlers should choose to sacrifice articulation so long as tone patterns can be preserved would suggest that at least in some tone languages the pitch pattern carries a load of information that can scarcely by significantly less than the segmental features.

The procedure presents enormous advantages from the point of view of both the user and the linguist attempting to describe it, when as in Mazateco, according to COWAN [25], the signal presents no detectable trace of articulation in the phonetic sense of the word. The whistler merely produces a melodic line, ideally identical in range and contour, but inevitably transposed up by several octaves, with that of normal speech (Fig.32). The listener is consequently presented with a sketchy outline of the sentence from which most of the substance appears to have been stripped. This, of course, is only what it sounds like to users of non-tonal languages; for the others, the situation appears in an altogether different light. Nevertheless a high degree of ambiguity must necessarily be built in. Cowan gives one striking example: first names which are prosodically identical (Modesto, Gustavo, Frederico--perhaps a misprint for Federico, but the form printed may well be current in Oaxaca--Ricardo) are said to have the same whistled form. If this is typical, and we have no reason to think otherwise, homonymic clashes must be frequent in Mazateco. They may not matter at all, or at least very much, because in the case of names, whistlers generally know whom they are addressing. In other cases, if Cowan's recorded material is in any way representative, the subject matter of the exchanges is such that the redundancy of the language at all levels (phonetic, lexical, syntactical) produces such a superabundance of information that more than enough can be carried by the flimsiest of frameworks. This would seem to invite the conclusion that in this respect tone languages in their whistled form do not compare favorably with the articulated types. In Gomero, Aas and Kusköy dialects, for instance, the degree of ambiguity is by no means high. There is no need to analyze the three languages from that point of view since they all behave in exactly the same way. (If we deal exclusively with the Silbo Gomero it is because, apart from the fact that it is quite representative, it is the one whistled language of which the present writers have an active knowledge, and whose spoken basis is thoroughly known. Aas would have done almost equally well in that respect but the moribund state of the whistle as practised there ruled it out of court).

What has so far been said of whistled tone languages, assuming that Mazateco is representative, suggests that it is totally impossible to guess anything at all about the phonetic structure of a word that is not part of the everyday vocabulary of the whistler--beyond its tone which is perfectly explicit. Any word from a non-tonal language can be only a meaningless noise for a Mazateco unless some accident produces a tone pattern corresponding to an existing Mazateco one. On the contrary there is no difficulty in obtaining from a Spanish or a Turkish whistler a spoken version of foreign words and names whistled to them, so long as their phonetic structure does not contain any element totally unlike anything that exists in Spanish. Thus the following forms were correctly interpreted by Esteban Herrera (Molinito, near San Sebastián, see map): Iwo [iβo] (Christian name of a Polish friend), Bordeaux [bordo] (thought of with a French pronunciation), Inka [iŋka] (pet name of a Polish friend), Bernay [berne] (village in Normandy), etc. The phonetic form of such words was easily identified, merely with a comment that the writer was talking, or whistling, nonsense. This is not to say that an articulated whistle is incapable of ambiguities--it is. For example *Manolo* and *mañana* whistled without special care can sound very much alike, although not identical, but it is easy to distinguish clearly between them whenever necessary. In any case it is difficult to devise contexts where homonymic clashes of the type Manolo/mañana could lead to serious misunderstandings. Confusion in practice arises only when two whistlers not completely familiar with each other's style--especially if they belong to different linguistic areas--are communicating under difficult environmental conditions. This type of situation does undoubtedly arise at La Gomera where the Silbo is used throughout the island and where there are slightly different forms of the whistled language. But where the area is more homogenous there is no such problem. It follows that in the nature of things a tonal whistle is bound to be at a disadvantage. The difference between the two types can be summed up as follows. A tone whistle can be interpreted only in terms of known tonal patterns, that is to say that it is phonetic only in a restricted sense of the word, and phonetic redundancy is ruled out, because the modulated carrier possesses one unique parameter from which it is impossible to infer the existence, let alone the nature, of other parameters of the spoken word. It is apparent that while tongue positions can be suggested by resonance pitch, and that the corresponding auditory response can be deduced from them, and that if the pitch is associated instead with the corresponding cord tone, everything else is automatically excluded. It follows that in the whistled form of a language like Mazateco no word-form has any existence without a meaning attached to it, whereas in the case of an articulated whistle a phonetic form, more or less complete, is suggested by the whistled version, so that actually meaningless words can be transmitted and identified at the receiving end.

It should not be inferred from the above paragraph that any comparison of values is being attempted. All types of whistling fulfill their respective function, otherwise they would have but a brief existence. All that is implied is that a tone language may be at a disadvantage in some respects as compared with others. Even so, it must be recognized that even if it happens to be a somewhat inferior instrument as an information carrier it has, against that, the merit of being a good deal easier to learn both to produce and to interpret. Articulated whistles require a not inconsiderable period of apprenticeship, especially on the decoding side. The present writer could whistle quite competently long before he was able to understand the Silbo at all.

Chapter 6

Extra-Linguistic Information Contents of the Signal

Communication systems may carry, in addition to the semantic contents of the message, certain items of information automatically encoded by the sender and perceived and analyzed more or less passively by the receiver. When the medium is speech, we find ten such items, which might be called extrinsic. They give clues to

1) The species.
2) The geographical origin at two levels or more (English, Southern British, East End Cockney; in French, France, Southern, Narbonne region as opposed to Marseilles or Bordeaux). This permits linking the sender with a social group, geographically defined (dialect).
3) Sex.
4) Relative age (three main classes).
5) Physiopathologic state (hoarse, asthmatic, Parkinsonian, nervous, lethargic, etc.).
6) State of mind.
7) Identity (individual characteristics).
8) Localization in space (direction, distance).
9) Culture (through choice of elements and their organization, respect of rules of association (syntax) with reference to a statistical standard called colloquial speech).
10) Aesthetics, admittedly a vague notion connected with culture but also with mood, social group, what might be called "good manners".

It is on the perception of these diverse elements that the biologic interpretation of the spoken message rests but we do not know exactly what physical speech parameters carry them. For example, despite numerous investigations, the knowledge of the physical structure of a particular voice still remains extremely nebulous, and it has so far proved impossible to express in a formula the acoustic identity of a given speaker. It is important to recall here one more point concerning the physics of the message. Apart from the information about spatial localization, which depends on binaurality and the level/distance ratio, we know that all the other information is integrally transmitted by a telephone line. Now, the band passed (1250-3500 Hz) is very narrow compared to the spectrum of the human voice (about 100-25,000 Hz). Through the use of filters we can further pare down the speech signal without markedly decreasing intelligibility.

We emphasize these elementary facts to pinpoint some of the difficulties posed by an acoustic signal as complex as speech. A simplification might be effected by first examining whistled languages because they are based on the modulation of a pure frequency in time, a parameter clearly easier to quantify than the formants of speech. But it is necessary to begin by establishing experimentally whether whistled languages can carry the same information as the spoken word. Only in Turkey were we in a position to carry out this investigation in any depth. We used, recorded on magnetic tape, a program of whistled signals to which unsophisticated peasants were invited to listen through a loud-speaker. We worked with different whistlers stationed some distance away who were asked to decode what non-semantic parameters they could detect. Here follow the details of the experiment.

The tests were carried out with both whistled and spoken words, the same words being used throughout, plus a certain number of sentences. The recordings were cut up into fragments, isolated words and sentences, and spliced together randomly so that both signals and whistlers occurred in a thoroughly haphazard distribution. In this manner a test tape consisting of 92 items was obtained. Informants (five men, two women) were invited to listen to it and answer the following questions:

For this particular word/sentence

Is the whistler male or female?
How old is he/she (young, mature, old)?
Do you know his/her name?
What did he/she say/whistle?

It goes without saying that the subjects, all Kusköy peasants, were quite unused to this kind of exercise which bore no relation to their daily experience. They felt rather out of their element and a little tense, because of the nature of the work, the instruments, and the questions which puzzled them not a little. Moreover the two women were in the presence of men and this, in a Muslim country where the status of females is still primitive, created an additional constraint. The moderately detailed results of the enquiry

Table 3 List of main words used in experiment on sender's identification

Karşiya	Bayirlik	Kepeksiz
Çarşiya	Çayirlik	Köpeksiz
Caplama	Bana	Ormana
Kaplama	Sana	Osmana
Kapici	Kalay	Yüzonbir
Yapici	Kölay	Yüzonbin
Bakalim	Parali	
Yakalim	Yarali	

Table 4 Summary of results of recognition experiment

	Responses		
	Positive	Negative	% error
Sex recognition			
Speech	230	7	2.9
Whistle	171	55	24.3
Age group recognition			
Speech	169	68	28.6
Whistle	97	129	57.0
Sender's identification			
Speech	143	104	42.0
Whistle	60	166	73.4
Word recognition			
Speech	227	10	4.2
Whistle	156	70	30.9

are exhibited in Table 3 and a summary appears in Table 4, where only the results for the five men, all efficient whistlers and therefore receivers, are listed. These results clearly call for some preliminary comments and qualifications. In the first place the artificial isolation of a word reduces the possibilities of analysis for a receiver unused to that sort of game. This explains in part why, even in the case of the spoken word, we did not obtain 100% success in word identification. Moreover, we had deliberately chosen to work with minimal pairs (see Table 5) so that the probability of error was maximum. Moreover, in the case of whistled items beginning with a consonant, the first sound is frequently impossible to identify. Finally, listening to recordings, that is to say, through a series of electroacoustic stages terminating in a loud-speaker, is bound to produce inferior results by comparison with a live source, especially with people not very well acquainted with loud-speakers. Nevertheless the figures and percentage

Table 5 Main results of recognition experiment for voice and whistle determination of sex, age, identity of sender and meaning of spoken and whistled words, for the seven receivers listed

		Speech				Whistle			
Receiver's name		Sex	Age	Individualization	Meaning	Sex	Age	Individualization	Meaning
Ali Cirit (male)	+	47	34	30	44	36	21	17	31
	-	3	10	20	6	9	24	28	14
	T			50				45	
Osman Cirit (male)	+	46	31	20	45	34	19	13	20
	-	1	16	27	1	11	26	32	17
	T			47				45	
Sadik Bebek (male)	+	44	36	26	44	39	24	16	35
	-	2	10	20	2	7	22	30	11
	T			46				46	
Adil Cindik (male)	+	47	31	28	47	32	16	12	30
	-	0	16	19	0	13	29	33	15
	T			45				45	
Mehmet Kosek (male)	+	46	37	29	47	30	17	2	32
	-	1	10	18	0	15	28	43	13
	T			47				45	
Kadin Civelek (female)	+	24	10	13	21	16	12	2	9
	-	0	6	11	3	11	15	25	18
	T			24				27	

+ = right
- = wrong

error show properties of the whistled signal which appear to have some significance, despite the difficulties designedly introduced into the experimental setup. The experiment was too limited in scope to justify submitting it to a statistical test and we shall merely indicate some of the conclusions one might tentatively derive from it, until the question is properly investigated.

It appears that the receiver can recognize the sender's sex with a fairly strong probability (75%) but cannot place him/her in an age group with any kind of confidence. Semantic recognition of even isolated words is very fair (70%) despite the fact that short patterns are much more difficult to identify than longer ones, especially in the absence of identifiable initial consonants. But it must be recognized that the possibilities of the isolated whistled word are greatly inferior to those of the spoken word for reasons which it is unnecessary to restate once more. This is particularly true at the level of the subgroup of features we are accustomed to call "word", divorced from a context in which mental processes are involved in the reconstruction of the whole context, even when starting from fragments of words. At the level of the sentence, the differences between the spoken and whistled media are greatly lessened.

In the artificial situation of recognition experiments with recorded material, results seem to indicate that, in addition to the semantic decoding, the sender's sex can probably be recognized, but not his/her age or identity. It must be pointed out, however, that certain whistlers can be identified even by non-whistlers if certain dental peculiarities are present, as happened in our own experience with a Kusköy woman who in some way whistled badly. In fact, we are of the opinion that this problem of individual recognition has two facets. Individual recognition obviously includes all the other information--sex, age, etc. In the Pyrenean, Turkish, Mexican, Canarian countryside, or within a particular valley, the social network is geographically clearly determined. One knows one's own neighbors, and in fact there is scarcely any identification problem at all. You know who is whistling from the right or the left, and the kind of question the enquirer asks generally brings a smile to the lips of an informant who knows well enough that if the call comes from above near that rock 2 kilometers away it's old what's-his-name who wants to say something. But place our informant in our artificial situation and he is lost, especially if faced with an unknown voice. We were, in fact, asking the wrong questions. Within the cultural milieu of the family, one may estimate that the number of individuals who communicate by whistles is of the order of 20 in these mountain communities and they indubitably recognize the peculiar characteristics, the signature of their associates, as we showed in our analysis of the individual variability of the whistle.

Sonagrams of minimal pairs whistled by a number of informants of both sexes from which a measure of individual variation may be obtained are given in Figs.34-36. Fig.34 refers to the word *Çarşiya* whistled by three men and three women; Fig.35 to *Karşiya*. Fig.36 shows the words *Sana* and *Ormana*; Fig.37 *Bana* with the graph of the spoken form for comparison. Close comparison of these tracings demonstrates the existence of extensive individual variations as regards the duration of silent intervals, pitch, syllable length, but the overall pattern remains very much the same. The type of variation observable in the first syllable of the words *Karşiya* and *Çarşiya*, pronounced, respectively, [karʃija] and [tʃarʃija], for example, is whistled by different performers with unequal duration and pitch range, but with very similar contours. Without the accuracy and potentialities of the chain ear-to-brain, a machine would scarcely be able to recognize or make much of this type of variation.

From all this, one might provisionally conclude that individual variability of the signal is sufficient to permit the recognition of a whistler through discrete personal elements known to be exclusively his own.

Sex Recognition

In the above context there is no physical characteristic which makes it possible to recognize the sender's sex, whereas in the case of the spoken word we are well acquainted with the spectral differences of the signal. This casts serious doubt on the validity of the experiments just described. The fundamental objection rests on the fact that the people in them belonged to the same village and everybody knew everybody else. Each was conditioned to individual peculiarities of each other's whistling style and it is these that made sex differentiation possible: the whistler's signature would be imprinted upon the voice.

Such an enquiry would present some theoretical interest if it were to be repeated on a larger scale with informants from different villages, unaccustomed to the test signals. It would be possible then to establish whether or not a whistle possesses physical characteristics similar to those of the spoken voice which make sex and age differences apparent.

The extra-linguistic properties of speech, which include in fact certain aspects of information listed above, characterize the personality of the sender as well as affective states associated with the physical aspect of speech. For example the significance of rate of delivery, variations of the fundamental frequency, intensity and its variations, as well as the combined effect of these parameters, has been clearly shown in studies on synthetic speech. In fact 15 adjectives have been proposed to define personality types--ambitious, intelligent, courteous, active, discreet, happy, fair, amiable, nice, sincere, trusting, religious, sociable, strong, likeable--and it would be no hard task to list a few more. The question is, to what extent do whistled forms of language allow decoding of this type? At the present moment experimental evidence is lacking because competent informants are not readily available and, even when they happen to be at hand they are generally ill-equipped to answer the relevant questions, or even usefully to take part in that sort of test. But what we do know strongly suggests that whistled systems of communication, so long as they are based on the spoken language and do not amount to mere codes, may well provide some extra-verbal information which, although less complete than that supplied by ordinary speech, is available from the time parameter, for example, that is rate of delivery, etc.

This, in our opinion, is an interesting field of study in a general way. We have scarcely skimmed it but it looks as if one could profitably spend some time investigating it properly. Among other things, it might be worth relating it to the gesture language of deaf-mutes since it is at least conceivable that this may also express some of these extra-verbal features.

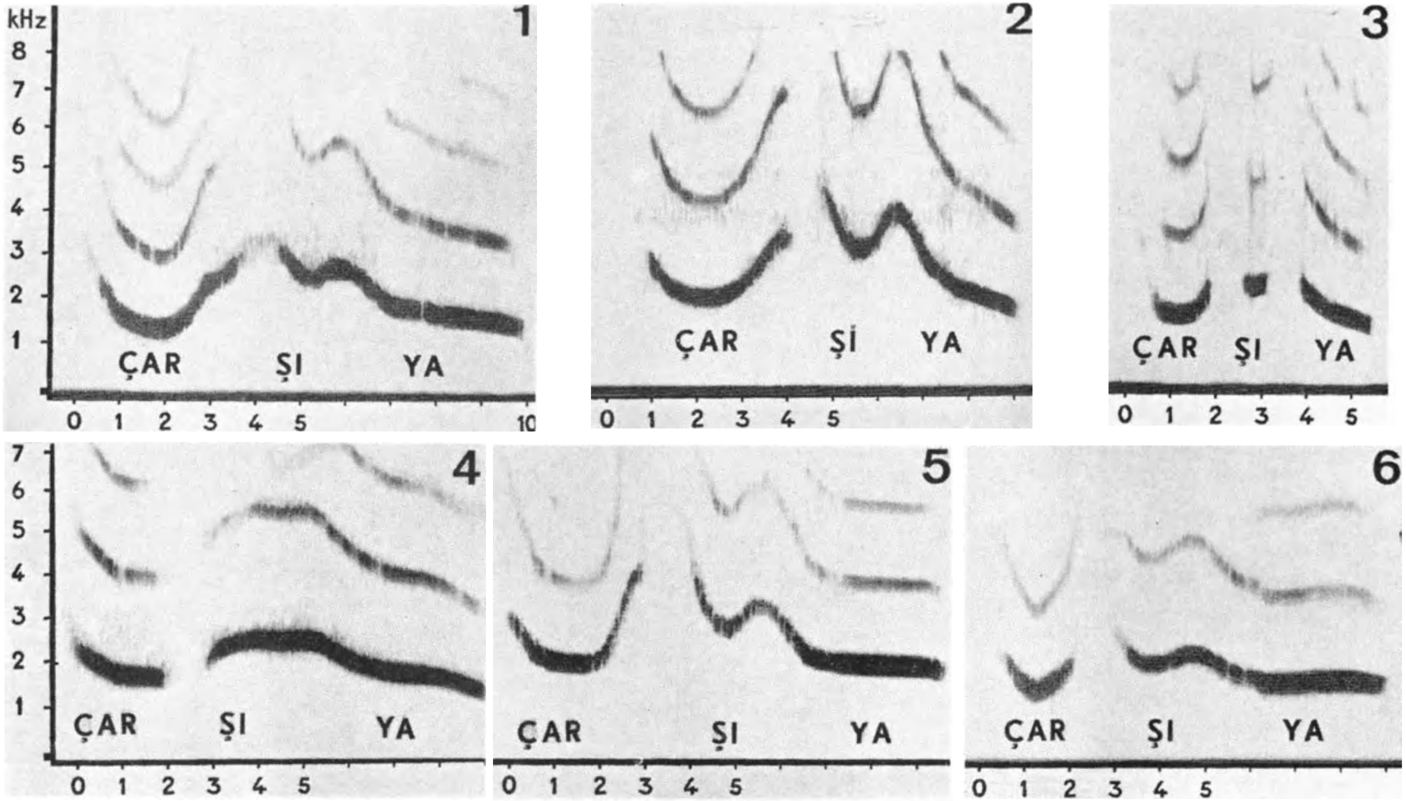

Fig.34 Sonagrams of the word *Çarşiya* by six whistlers (Turkish)

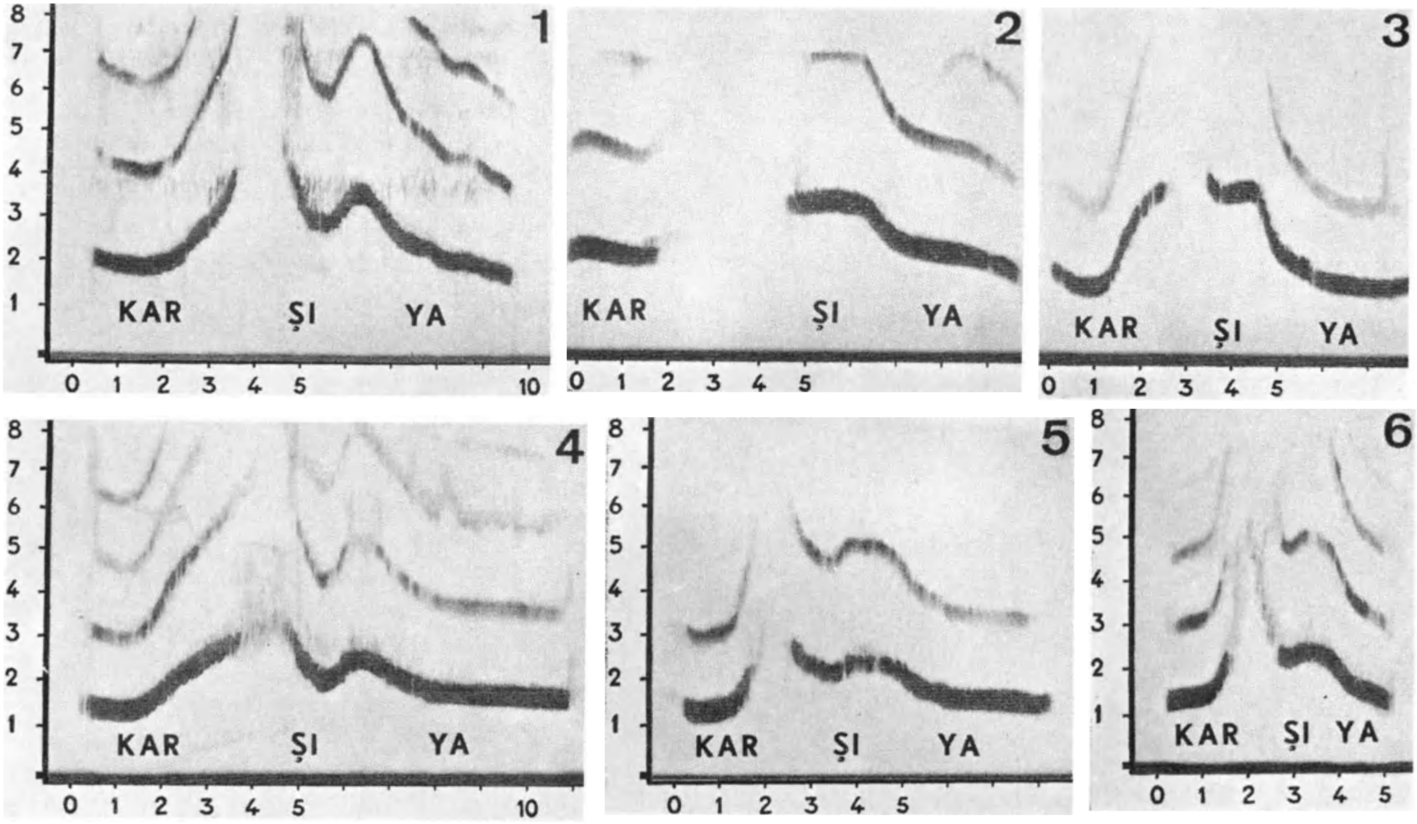

Fig.35 Sonagrams of the word *Karşiya* by six whistlers (Turkish)

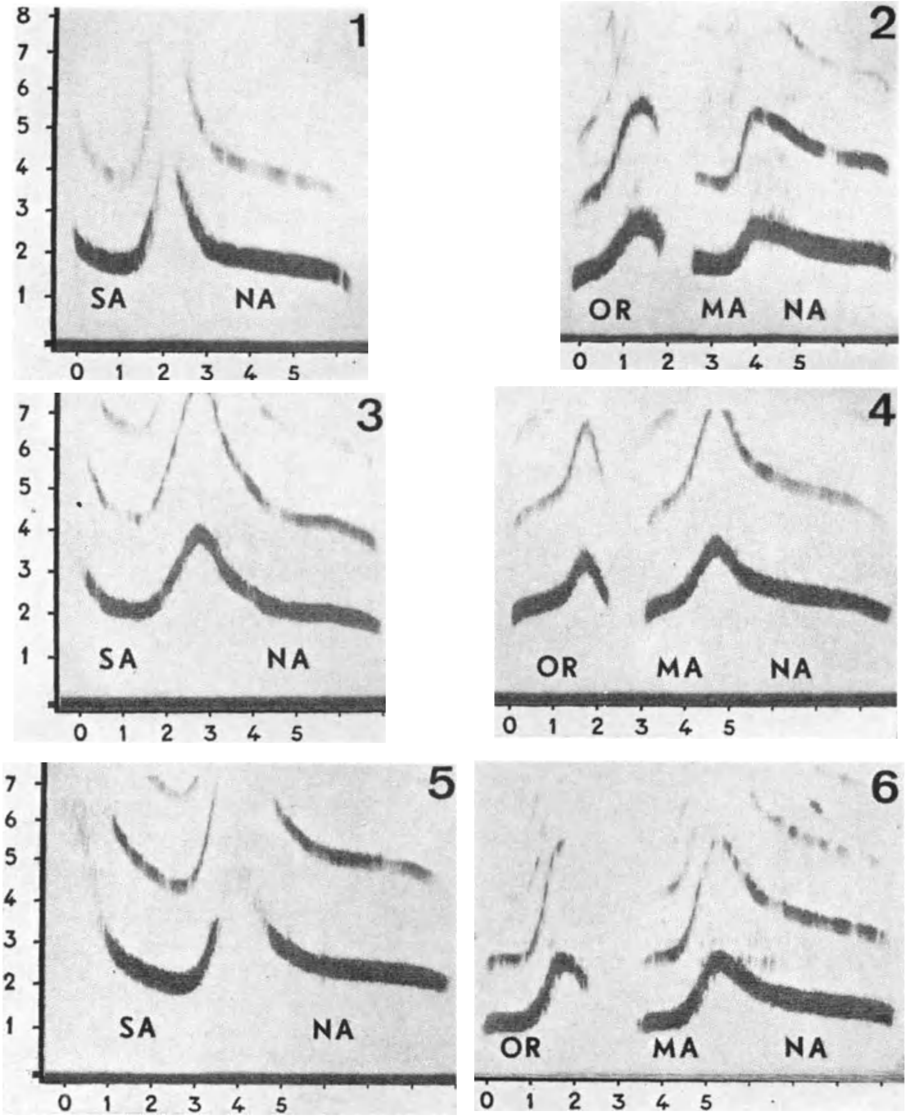

Fig.36 Sonagrams of the words *Sana* and *Ormana* by three whistlers (Turkish)

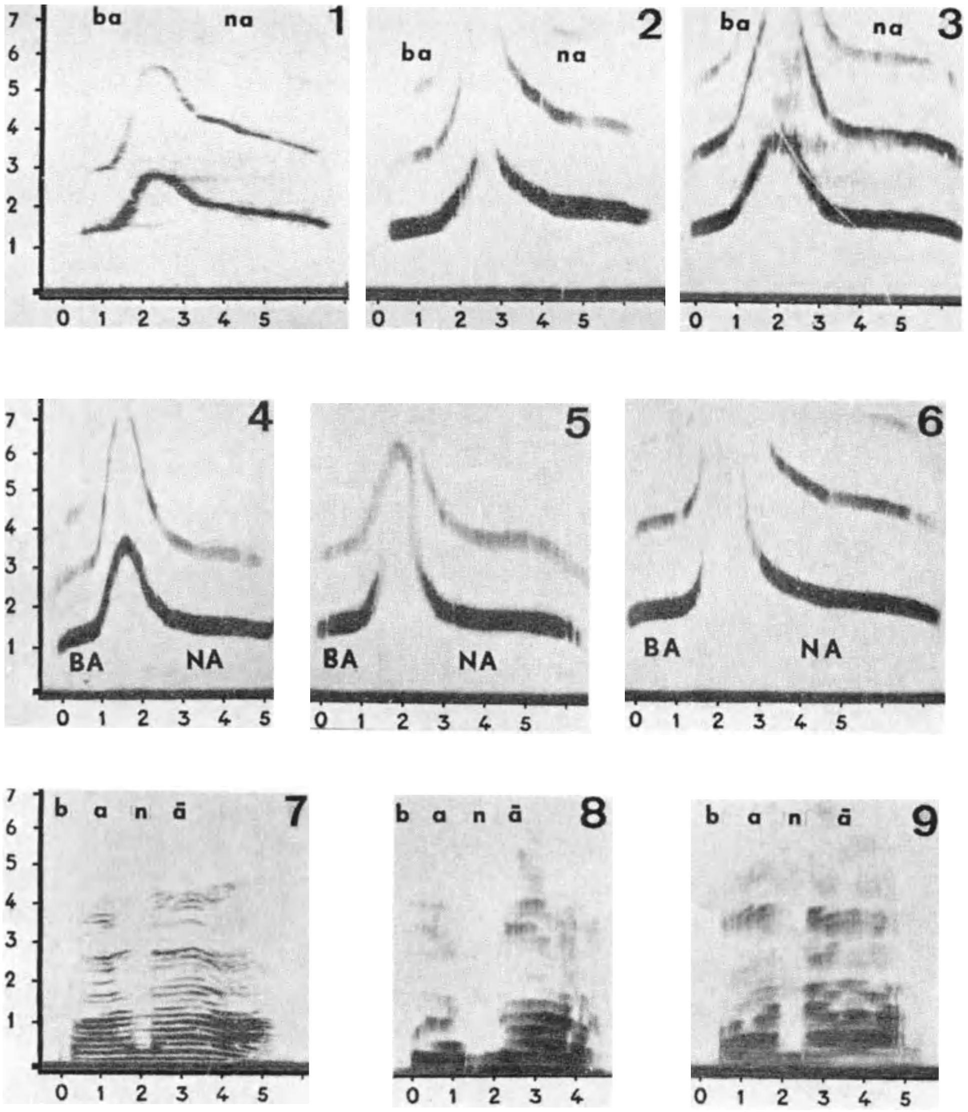

Fig.37 Sonagrams of the word *Bana*, whistled and spoken, by three whistlers (Turkish)

Chapter 7

Whistling in the Animal Kingdom

Numerous animal species are equipped with acoustical communication systems [11-75]. Over the last 25 years or so many investigations, often in depth, have led to a fair understanding of their acoustic behavior, of their vocabularies and of their "speech" organs, in the cases of both invertebrates and vertebrates. Among the latter, in particular birds and a few mammals, some species emit characteristic whistling signals. This may be one reason why the Turkish village of Kusköy, where whistled communication is practiced, has been so named; it will be recalled that Kusköy means "place of the birds".

An obvious question suggests itself at once: might one speculate on the possibility of the existence of some link between animal and human communication? Of course the problem concerns not the mechanism of sound production but rather the whole question of language, this notion being defined and demarcated with the utmost rigor [12,58,72]. Clearly it would occur to no one that the drumming of woodpeckers, that is the noise made by the rhythmical tapping of trees by these birds, which is a mating call or a territorial claim, could possibly be equated with the drum languages used by hundreds of African tribes [30-46]. This somewhat naive parallel--which in fact poses the question "is there such a thing as animal language?"--seems to deserve analysis, at least as far as certain birds as well as, among mammals, Delphinidae, are concerned.

It must be emphasized that although both man and animal exchange signals--within the limits of the species, of course--for the purpose of sending varied and often even complex information, in the case of animals vocabularies, are limited. We always find close, finite systems, genetically based, even when, under natural conditions, parts of them are "learned" in a manner that we are now beginning to understand. On the contrary, man's linguistic system is entirely learned, therefore not genetically based and, moreover, is typically open, that is to say, infinite. This constitutes one of its most essential characteristics.

From this we are not entitled to deduce that the acquisition of a human-type language, with its combinatory features at several levels, must be beyond the means of any animal. KELLOGG [41,42], KOHTS [45] and HAYES [38] experiments with chimpanzees, based on speech, did fail. However, those of GARDNER [33], PREMACK [68,69], FOUTS [31] and others, based on either the gesture language of deaf-mutes or an artificial language made up of visual elements, with results which have been made widely known, have proved that the brain of the chimpanzee, in the artificial conditions of an upbringing in a human milieu, is capable of learning, memorizing and combining the elements of such languages in the way a human child does, at least up to the level of early childhood. We shall probably learn in the near future what level a chimpanzee can reach in these circumstances and what mental characteristic, proper to these individuals, will dominate the handling of the acquired language. Only experiments of this type will supply answers to these fascinating questions, which at the present moment remain open.

But for the biologist the most important fact is that in nature, in natural social circumstances, the species neglects such a system of which its brain is undoubtedly capable on the functional plane.

Now it has been suggested that what could be done with chimpanzees could just as well be tried with dolphins, but using whistles instead of optical signals. Delphinidae, which are marine mammals, although they were known before to sailors and zoologists, have been "discovered" on the biological and psychological planes only during the last 20 years or so [29-62]. They have proved to be extremely interesting animals as regards both their behavior and their aptitude for learning, as revealed by their performance of the tricks we can admire in marine circuses. Moreover they emit characteristic noises, consisting of varied signals, short pulses used in their sonar system, and others which are chiefly pure frequency modulations, i.e., true whistling, probably used for the purpose of communication. These animals have a very well-developed brain at the cortical level and it is generally agreed nowadays that their intelligence is about equal to that of chimpanzees and dogs. However we must admit that our criteria for the evaluation of intelligence are somewhat subjective, and also that the investigation of their intellectual capacity is far from complete [40,58].

Let us first state the problems of dolphins. Their whistling, variable according to the species, covers a band of several frequencies, generally

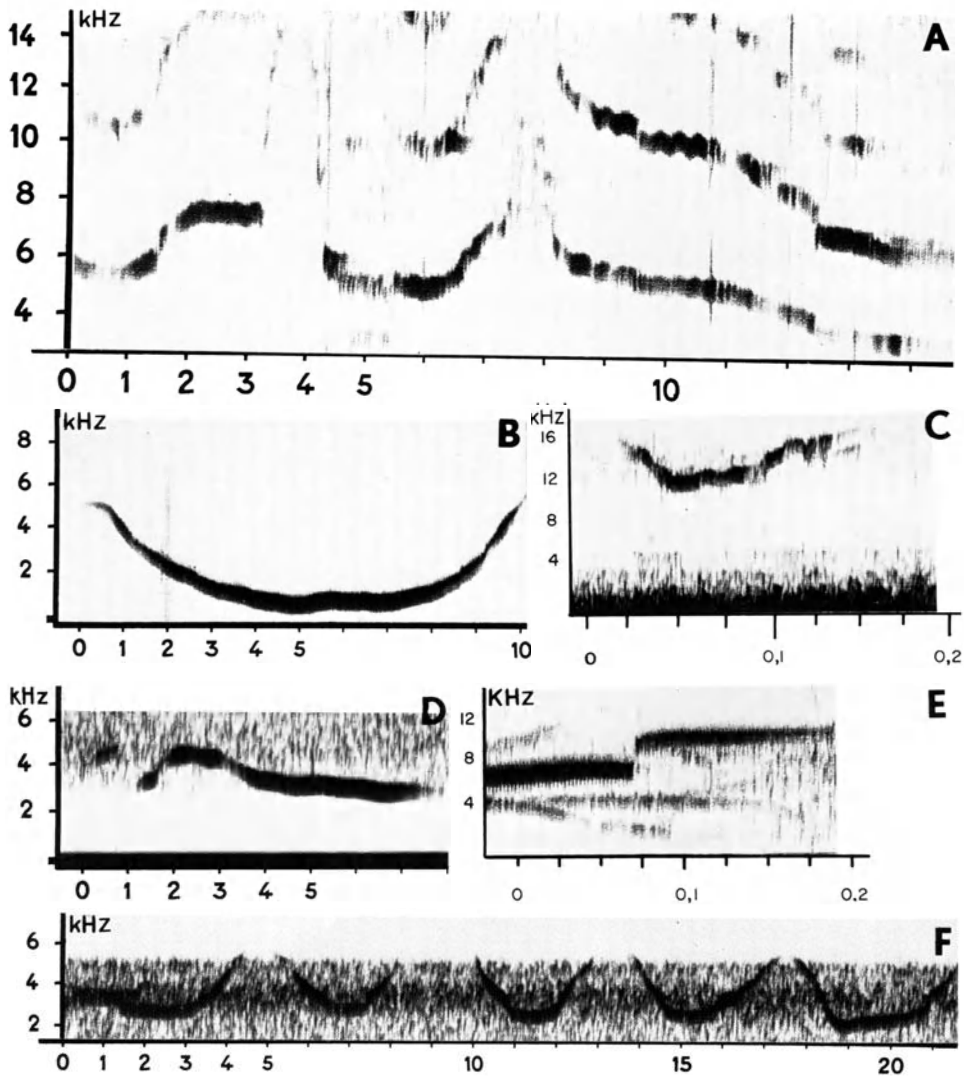

Fig.38 Sonagrams of whistles. A: Pilot-whale (*Globicephala melaena*). B,C,D,E,F: Saddle-back dolphin *Delphinus delphis*. Time scale: 0.15. Underwater recordings and analyses made by BUSNEL and DZIEDZIC [15]

between 4 and 30 kHz. Numerous analyses reveal variations of frequency in time which researchers have tried to classify as is usual when attempting to break a code, but without any success [15,19,29]. It is in fact a major problem which so far has remained unsolved, for no one has yet succeeded in establishing a correlation between a signal and a response of the receiver that would allow one to attribute a semantic content to the signal. Even in the case of alarm or distress signals, that is to say those that can be obtained

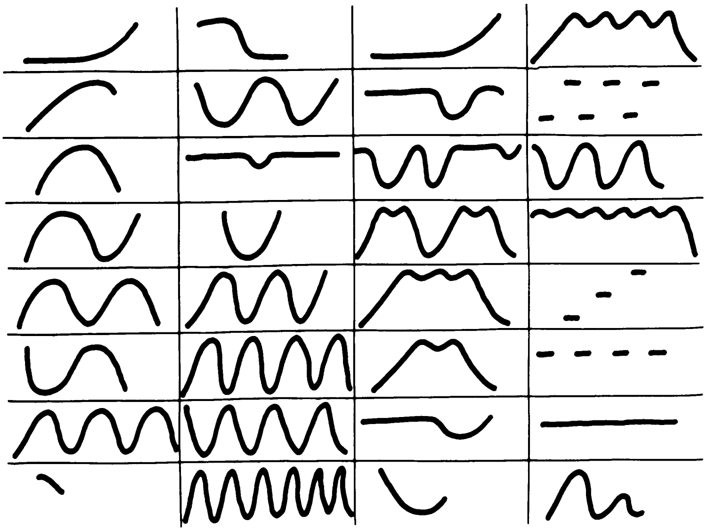

Fig.39 Contours of whistles of different porpoise species (after DREHER [29])

from frightened animals, or animals that find themselves in stress situations, it has proved impossible to establish a valid semantics of the signal that could be based on reactions of the receiver [15,49,50]. This does not mean that these signals have no semantic contents, only that they have not been established. Furthermore the physical characteristics of the signals appear to vary between wide limits from one individual to the next, which makes it improbable that they possess a specific semantic content. It is to be regretted that the scientific literature of the subject, and especially popular literature, should contain inaccuracies and romantic extrapolations which give a completely distorted view of the problem. Scientifically speaking, we must admit that we do not know up to this day how to interpret a single acoustic signal emitted by a dolphin and it is quite unjustified to credit these animals with a language, in view of the fact that we have no conception of the size of their vocabulary, if any, or of the nature of the signals they send.

It is a fact, however, that these animals do communicate together, or at least exchange signals, as has been established through numerous observations [48]. But we do not know what they send. BASTIAN [3] thought he had demonstrated that objective data in given situations were transmitted, but his experiments have not been confirmed, and the hope entertained that a code had been shown to exist has had to be abandoned for the time being.

An interesting trait of these animals' behavior in captivity, at least in the case of *Tursiops truncatus*, is their attitude to man and their habit of emitting acoustic signals in his presence. In the course of their association with the trainers, there have even been reports of their attempting imitations of the human voice, although this fact has not been confirmed. But it has suggested that teaching a human language to these animals might be feasible [50], along the general lines of what has been tried unsuccessfully with human speech in the case of chimpanzees.

The dolphin's vocal apparatus is most complex and, although we are well acquainted with the anatomy of the several organs which can generate sounds [6], there is no agreement on the subject of phonatory mechanisms and sound sources, nor is there any sure knowledge regarding the regions of the head from which the sounds issue. But this question of phonation, raised here to recall the experimental difficulties and our own uncertainty, is not an obstacle to the general discussion. Much more important is the fact that dolphins can learn, memorize and emit whistles. It was then tempting to examine the possibility of teaching them, instead of speech, for which they are not particularly well equipped anatomically or phonetically, a whistled language, better suited to their natural characteristics. That was initially suggested by BUSNEL [12] and attempted by BATTEAU [4]. This researcher's untimely death did not permit the experiment to be taken very far but his attempt deserves to be recalled here.

Batteau, who was not acquainted with a whistled language, used electronic whistles produced by a generator. These whistles, ranging between 4 and 12 kHz, were emitted by an automatic setup called Vocal-Trainer by the author. Simultaneously the apparatus analyzed and compared the animals' responses with the signals emitted. By conditioning the animals he showed after a few months of experimentation that dolphins could be trained to associate a body motion with an underwater acoustical signal. Later they could be trained to reply with whistles to acoustic signals of great complexity and to imitate them, copying pitch contours very accurately [4,54]. This first step, admittedly only a preliminary one, proves that the dolphin can reach the earliest human stages of echolalia, that at which the child learns to use his speech organs. Clearly the association of the signifiant with the signifiê should follow. This was easily achieved in the case of chimpanzees, and it encourages one to hope that the same could also be done with dolphins. However much remains to be done in this field and it is still a matter for the future.

Although these conclusions are unspectacular and far removed from the science-fiction tales of Hollywood, it must be said that much is possible, as far as dolphins in captivity, i.e., under training, are concerned [4]. On the plane of whistled languages it is in theory perfectly possible to use this type of FM as a basis for language teaching.

We shall now say a few words about birds, which have been the subject of extensive research in the field of sound signals. We shall give only a brief account of the situation, focussing our attention on certain anatomical and functional features common to both man and bird.

The sounds emitted by birds are produced by the air stream which is made to vibrate by the elastic membranes of the syrinx whose variations of tension determine the pitch variations of the sound through the neuro-muscular system that controls it. Although the anatomy and physiology of the syrinx differ from the human larynx these organs obviously play a similar role. Now, the neuro-muscular complex and certain properties of the central nervous system involved in the production of sound are in some ways surprisingly similar in man and bird [56]. In the first place we find in birds the same lateralization of vocal control as we find in man [64]. For example, although the male chaffinch's syrinx is approximately symmetrical, with nerves originating in both cerebral hemispheres, cutting through these will produce vastly different results according to the side from which they emanate. If one cuts through the nerves that serve the right branch of the syrinx the bird's song will scarcely be affected whereas cutting those of the other side produces drastic results: most of the elements of the song either disappear completely or are thoroughly changed. After the operation the bird cannot sing normally any more, but if the subject is a young male which has not yet reached the stage of normal phonation he will be capable of normal song during his adult phase even though the left nerves have been cut through [64]. This is very much like what happens in the case of man; a lesion on the dominant side in a young child is compensated by the other hemisphere which becomes capable of controlling the voice normally. This feature of lateralization which must presumably be present at the level of the two hemispheres in birds (especially passeriforms and parrots) and is therefore similar in both groups, clearly does not mean that birds possess a language, but we must notice these very similar properties of nervous systems which are otherwise quite different.

We also find in certain birds the learning of signals which can only be based on auditory memory, an important feature also present in man. A great many species of song birds (finch, chaffinch, etc.) have to learn their vocalizations from adults during their first year, and these will only be stabilized later. If such birds are brought up under conditions of acoustic isolation, they will certainly produce sounds correct enough as regards time and frequency, but lacking those variations which characterize the song of the adult bird [57]. If they are made deaf by surgery around the age of 3 months [43,44,56] the song will have a quite abnormal structure; the temporal structure and the complex variations of the normal song will be completely disorganized. Thus we find that phonation is controlled through audition. It is the same feedback mechanism as the one found in man.

Even though adult birds generally have stereotyped voices, the conditions under which they are established vary according to species. Some need a model to learn from and auditory feedback, for example the chaffinch and the white-crowned sparrow. On the other hand, the common domestic hen and the ring-dove acquire normal songs even if made deaf during the first days of their existence [63]. Certain birds can learn to imitate, others cannot.

For some species there is a critical period of apprenticeship, usually one year for passerines, whereas others, like parrots, are still capable of learning when they have reached the age of 20 or so. Regarding birds' characteristics it is important to note this critical period from the time of emission of what is known as the "subsong", in which the intensity of vocalization is low and its structure variable. This corresponds to the stage of "babbling" in human children. It is a spontaneous phonation (eulalia) devoid of contextual significance. In birds this depends on auditory feedback and is unlike what happens with deaf children who babble in any case. Another consequence of the apprenticeship and its relative plasticity according to species brings about acoustic variations in the realizations of the signals. This depends on chance differences in the environment and the geographical origin of the parents. These variations could be termed "dialectal" when they become perpetuated in circumscribed areas and associated with a degree of sedentariness. We find in man the same phenomenon which is perpetuated locally in a similar manner.

The vocalizations of so-called song birds (pass. and others) have physically varied structures frequently including whistles, i.e., modulations of pure frequency, like those of human whistlers, but generally within a higher frequency range (3 to 12 kHz) and with much faster rate of change. Whistles are emitted on the expiratory phase of respiration, at least in the case of some birds like the canary which have been the object of a study [18]. A detailed analysis of the physics of birds' vocalizations will be found in GREENWALT's treatise [36].

Apart from these anatomical, physiological and physical characteristics of birds' vocalizations, which are interesting in themselves, we must cast a glance at the questions of birds which mimic. If in the wild some species mimic neighbors belonging to other species, and in the extreme case of parasite birds (*Viduinae*, NICOLAI [59,60]) produce a perfect replica of the signals of the hosts, only in captivity do such birds as parrots and mynah birds imitate the human voice. They are for us only of secondary interest, although they are capable of learning whistled tunes. This condition of captivity brings us back to the questions of the chimpanzees and perhaps dolphins dealt with above, underlying the artificiality of the surroundings. In fact, birds do not reach anything like the stage of chimpanzees and they never succeed in associating sound and object in assigning a label to the object, the essence of language activity whether spoken or whistled. It is certain that birds do not achieve the complex combinations found in human languages, at least at the semantic level of the receiver. For although we are often struck by the extreme variation of sound combinations in song, such combinations, as far as it is possible to discover experimentally, have nothing to do with the meaning of the message for the receiver, at least in the present state of our knowledge.

The feature of human whistles imitated by certain birds in the wild deserves mention. After some observations by Classe at La Gomera, who heard blackbirds spontaneously imitating complex whistled signals such as Federico, María de Los Angeles, the results obtained by TRETZEL [77-79] and NICOLAI [61] who specifically studied spontaneous imitations are worth quoting because they refer to whistles. Tretzel describes spontaneous imitations of human whistles which he was able to record. One case refers to crested larks (*Galerida cristata*), in the neighborhood of Erlangen in Bavaria, who imitated four whistled signals used by a shepherd to direct his dog. These birds repeated these whistles, sometimes with variations, and even combined them, but never mixed them with their normal songs. The intervals as well as the rhythm were accurately respected. Some distance away from the shepherd

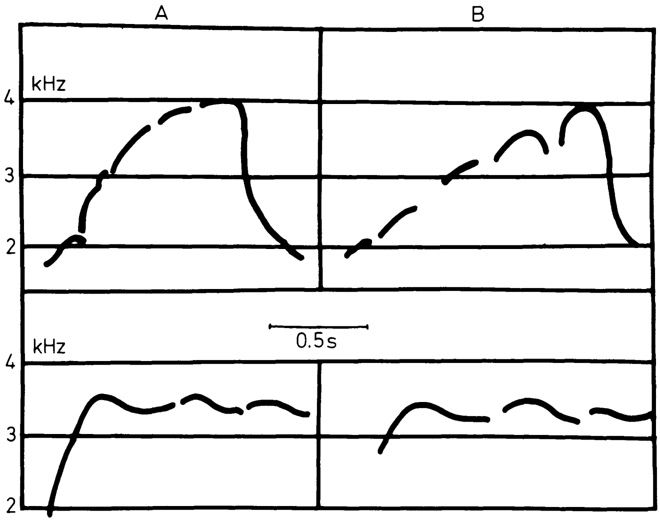

Fig.40 Sonagraphic contour of whistles used by (A) a shepherd and (B) their imitations by a crested lark (after TRETZEL [77])

Tretzel found another mimic lark who must have been taught by one of the first birds he had observed, thus showing that a tradition could be transmitted. The same writer observed in the Garmish-Partenkirchen region a little later similar imitations by a blackbird (*Turdus merula*) who copied whistles that for years a man had used to signal his cat. The model whistled rather roughly four notes between 1 and 2 kHz, with variations of pitch and rhythm. The blackbirds transposed the whole motif up a fifth and introduced ornaments, as one introduces embellishments in eighteenth century music. Some of the imitations were within a semi-tone of the original.

In the course of the last 200 years or so German peasants of the Hesse regions who have bred various birds such as canaries and bullfinches have noticed the extent to which these species can memorize and reproduce the acoustic signals of either their parents or their breeders. They have generally used this faculty to teach the birds to whistle short popular songs. These cage birds are able, on the average, to learn about sixty different notes and two short tunes [59-61]. Sonagrams show that these birds follow very accurately the tempo and the rhythm of their human tutors. Generally they transpose their whistles to a higher octave, more appropriate to their natural whistling frequency range. A number can even whistle the same tune at two different pitches, one higher and one lower than that of the teacher. Those that know two songs know that each is an independent unit. When it gets into difficulties during its performance of a tune because of the complication of a given passage, the birds tries to recall the piece either by going over the preceding section or by repeating the whole. Perhaps the most interesting fact observed by Nicolai is this: if the teacher stops the bird's whistling in the middle of the performance and continues it himself either singing or whistling, the bird stops. But, when the man stops in his turn, the bird continues the tune from the place where the man ends. These alternations between bird and man whistling show that the bird has memorized the complete melody, as an integral form. This closely resembles the learning of stereotyped sentences by man, such as proverbs or lines of poetry. The bird then, under these conditions, is capable of mastering complex melodic and prosodic data. We may say then that certain species of birds have many points in common, at the acoustic level, with human whistlers and this is why we have found it advisable to recall briefly the functional data and the conditions of apprenticeship. But we must guard against taking this too far. The parallelism between man and bird, although obvious at certain levels, does not go beyond a certain limit, even though on the plane of evolution at the level of the central nervous system it is undeniable. Even if birds whistle and mimic after memorizing, they do not, as far as we know now, use anything but a system of undoubtedly complicated signals which nevertheless does not by any means reach the complexity of human languages. Vocabularies invariably remain closed, despite the astonishing melodic variations one can observe; variations which remain, until proof to the contrary, semantically unimportant for the receivers, except perhaps that they may carry the acoustic signature of the sender who is thus more accurately characterized. To conclude: the information we derive from the comparative study of the problem of communication in the animal kingdom, of which man is at present the ultimate evolution, shows that the feature of communication is deeply imbedded in the history of species. For vertebrates it is among birds that we see the fundamental characteristics appear, already similar to those that are part of the human makeup. These are basically those of the central nervous system and also link up with the sensory periphery both in the passive field of audition and the active field of acoustic emission. Among mammals, the dolphin most probably has a central nervous system even nearer ours but our knowledge of these animals is still very incomplete.

Results recently obtained with chimpanzees show that, with a different physical system and under conditions of breeding and training with man, the principles of human language can be taught to that primate up to a certain level [51,72]. Human whistled languages, which represent one facet of the problem of language, might, through training, be usable by animal species possessing centrally the cerebral mechanisms that allowed their manipulation, which is not the case with birds, but could theoretically be possible with dolphins.

Conclusions

It will no doubt have been noticed that not once throughout this monograph have whistled languages been referred to as speech surrogates. In the opinion of the present writers there is nothing to recommend the use of this term. Whereas the sign language of deaf-mutes, for instance, is truly a surrogate since it is a substitute for normal speech, whistled languages do not replace but rather complement it in certain specific circumstances. In other words, rather than surrogates they are adjuncts. Looking at the question from a slightly different point of view, when a Gomero or a Turk whistles, he is in effect still speaking, but he modifies one aspect of his linguistic activity in such a way that major acoustic modifications are imposed upon the medium. Nevertheless the fact remains that he is still using the same medium, although in a vastly different shape. The procedure would be identical if one were to speak into a machine designed to convert the spoken word into whistled signals. It will be remembered that something of the sort was attempted recently in the U.S., with what long-term success we do not know, in the hope that communication with dolphins would thereby be facilitated. At the receiving end, the acoustic signal is mentally converted back into the original verbal image that initiated the chain of events, so that in effect ordinary language is still present at both ends of the chain. The whistled signals occupy the middle, but most of the normal linguistic events are not replaced. This in itself may not be a fact of major importance, but to call the Silbo, for example, a surrogate is in effect equivalent to lumping it with the sign language of deaf-mutes when there exist between the two vital differences.

One striking aspect of whistled languages of all types is their appearance anywhere in the world. They do not seem to be linked with any particular linguistic group or language type. It has been shown that what seems to be responsible for their emergence is a combination of topological and ecological features. And of course users are not slow to notice their value as secret languages. The importance of this aspect varies greatly, from minimal in the Canaries, for example, to considerable in the New World and, presumably, elsewhere. In general it seems that the value of the medium, particularly in the case of articulated whistling, is mainly in its possibilities for telecommunication. We know that at La Gomera, Aas and Kusköy whistling is never used at close quarters, except in fun, whereas it appears from Cowan's and others' accounts that the secret side of, say, whistled Mazateco has assumed great importance since it is frequently used when the voice would be perfectly adequate for the purpose of conversation. On the contrary, when the Silbo was tried instead of field telephones during the Spanish Civil War, it was as secret as a code a copy of which would have been supplied to the other side. We are aware of only one case of whistled language used exclusively for secrecy and not for telecommunication, that of ñañigos (cf. footnote, page 22) during the last century. But in everyday life where a telephone tends to be more generally useful than a code book, whistled languages of the Canarian and Turkish type are extremely efficient substitutes for telephones. They are greatly superior to drum and similar languages since they function roughly at the same rate as ordinary speech, certainly faster and more clearly than shouted speech, and enormously faster than most drum languages which often have to rely upon a large amount of redundancy if they are to be at all intelligible. Difficult terrain and a low density of population favor the development of whistled languages. Not unexpectedly their usefulness decreases as means of communication improve: they tend then to die out. Aas is a case in point. But so long as a region remains sufficiently backward they continue to flourish as at Kusköy.

As we have already noticed, a whistled language may be regarded as an acoustically simplified version of speech. Lexis, syntax, and to a large extent (at least in some cases) phonology, retain their integrity in the passage from the spoken to the whistled medium, but a phonatory mechanism of (probably) maximum simplicity is substituted for another, very much more complex, one. In this respect we are justified in using the term simplification. The several parameters that specify the acoustico-auditory aspect of an utterance are replaced by a frequency modulation of a simple wave-form; that is to say, the concatenation of timbre variations of normal speech appears in the other medium as a mere variation of pitch. In the case of tone languages the simplification could hardly be more thorough going since all the phonologico-phonetic factors are purely and simply eliminated so that we are left with one supra-segmental feature--two if duration (quantity) carries a great deal of information in the language concerned, as might be the case in, say, Finnish. Not surprisingly, in the whistled form of tone languages, a good deal of ambiguity unavoidably creeps in. It will be remembered that COWAN mentioned four Christian names identically realized in whistled Mazateco [25, 26]. On the other hand, the efficiency of the articulated type is extremely high and can be made to approximate that of speech, as regards intelligibility, whenever necessary, without having to introduce any complication or convention.

This is really most curious and one may be tempted to wonder why a form of communication that is so economical as to the number of physical parameters involved should not have been universally developed by man instead of the system of signals we call speech, with its complex combinations of movements by a large number of organs which have to be coordinated with the utmost precision. But the answer is not far to seek. Phonation, i.e., the production of noise by the action of expired air on the vocal ligaments, is one of the most natural activities of man, as well as of a large number of animals. The first act of breathing performed by a new-born baby is also its first act of phonation. The infant, long before he acquires any real control over his muscular system, seems to find pleasure in making an assortment of vocal noises, most of which, incidentally, occur in one or another of the tongues of men. The physical basis of speech then involves little conscious effort and is there all the time to build on. Whistling is another matter; it cannot be efficiently performed by the toothless, so that it is not available to the very young or the old. It is not a natural activity, proves difficult for many, impossible for some, so that it is in fact beyond the reach of a good many people. Finally, a great deal more expenditure of energy is involved in its production than in speech. It is clear that the advantages of the simplicity of a system of whistled signals are more than outweighed by the restrictions imposed upon it by the mechanics of its production.

As for the future of whistled languages, it is not difficult to prophesy. We know what happened to the Silbo, which once flourished throughout the Canaries and now survives only at La Gomera, and to the Aas version, now on the very verge of extinction. They have remained in common use only where modern technology has not yet reduced their usefulness to zero. In some locations, e.g., the Gomero and Turkish hills, they stand an excellent chance of survival, at least for a good many years, because roads and telephones are still largely things of the future. But even there they are fated to die out eventually. Fortunately many of them have been studied and recorded and will

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